Industrial QUALITY CONTROL

VOL. IV JANUARY, 1948 NO. 4

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AND

Fourth Annual Quality Control Clinic

Rochester Society for Quality Control

FEBRUARY 16-17, 1948

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During the Summer and Fall of 1947, active work on the part of a number of energetic American Society members in various parts of the state resulted in organization of the Tennessee Society for Quality Control with Mr. Parker D. Deans as its first President. In November, this Society applied for recognition as a Section of the American Society, and such recognition was voted unanimously by the Executive Committee at its meeting in Rochester on 6 December, 1947.

Since the early days of its organization, the Iowa Section has had a number of active members in Minneapolis and St. Paul. Interest in Quality Control matters has been growing apace in the Twin Cities, and during November, these members formed the nucleus for organizing a new Minnesota Society for Quality Control, which applied immediately for recognition as the Minnesota Section of the American Society. Recognition of this Section was also voted unanimously by the Executive Committee at its December meeting. Mr. S. C. Amren is the first President of the Minnesota Section.

With these additions, the American Society now has twenty-nine active Sections.

NOTES

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   (a) Submit a minimum of two copies of the paper, each typewritten and **double-spaced.**
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Industrial Quality Control

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Membership in the American Society for Quality Control is available in three grades through local Sections or directly through the Executive Secretary. Annual dues for direct national membership are: for Members, $5.00; for Senior Members, $10.00; for Fellows, $15.00. The Member grade is open to any person of good character who is 21 years of age and engaged or interested in quality control. Information covering higher grades of membership and concerning local Sections may be obtained from the Executive Secretary.

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Cost of Back Issues

Most back issues can still be supplied individually at $1.00 each, but certain issues are now available only in complete volumes at $5.00 each. Volume I includes the six issues from July, 1944 through May, 1945. Volume II includes the six issues from July, 1945 through May, 1946. Volume III includes the six issues from July, 1946 through May, 1947.

ANNOUNCING THE

Second Annual Convention American Society for Quality Control

AND

Fourth Annual Quality Control Clinic Rochester Society for Quality Control

CHAMBER OF COMMERCE, ROCHESTER, NEW YORK
MONDAY AND TUESDAY, FEBRUARY 16 AND 17, 1948

Plans are rapidly maturing for a program of subjects and speakers that will make the Second Annual Convention of the American Society a fitting successor to the first one, held in Chicago last year. The Rochester Section and the Industrial Management Council of Rochester will be hosts to the Convention this year.

The program as tentatively outlined in the November issue of the magazine has been somewhat modified to provide for an integrated sequence of presentations. There will be two luncheons, but only one dinner meeting. The afternoon of the first day, and the morning of the second day, will be devoted to general session meetings. The clinical sessions will be held in the afternoon of the second day. Around this core of formal meetings, ample time has also been provided for Board and Committee meetings of the American Society, for visiting the gage exhibits, and for general, informal fellowship.

The general theme of this year's meetings will be "Quality Control in the Coming Buyer's Market." This will be divided into two subgroupings:

(a) Stock Taking General Sessions;

(b) Advancement Programs and Clinics.

The first luncheon speaker, and each of the two speakers at each of the two general sessions, will talk on topics that will be tied together to cover the general theme of the conference. All subjects will follow a coordinated pattern bearing on quality control in relation to Management, Sales, Engineering, Purchasing, Manufacturing, and Inspection.

The dinner session will be the Annual Dinner Meeting of the American Society for Quality Control. The speakers at this meeting, and at the second luncheon meeting, will be men with outstanding reputations in the field of statistical quality control. Their talks will cover this field generally in terms of the past, present, and future role of the science of quality control as an aid to industry.

Hotel accommodations are available as shown in the accompanying table. Guests are urged to make early room reservations directly with the hotel, mentioning that they are coming to the Convention.

The price for a full, two-day, conference ticket, including the two luncheons and one dinner, is $15.00. Split tickets will also be available, but by days only — not for individual sessions. The fees on this basis are $10.00 for the Monday sessions (including the noon luncheon and the Convention Dinner), and $7.00 for the Tuesday sessions (including the noon luncheon). Requests for conference reservations should state clearly what coverage is wanted, must be accompanied by remittance to cover the reservations requested, and should be addressed to

Mr. Joseph C. Warren
Industrial Management Council
12 Mortimer Street
Rochester 4, New York.

As in previous years, the gage exhibits will be a worthwhile feature of this conference. There are still a few spaces available for exhibits. Inquiries regarding procurement of exhibit hall space should be addressed to

Mr. William Myers
Gleason Works
1000 University Avenue
Rochester 3, New York.

Hotel	Address	Rate Per Day Single Room	Rate Per Day Double Room (Twin Beds)
Powers Hotel	34 Main St. W.	$3.00 to $4.75	$6.00 to $7.25
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Hotel Seneca	26 Clinton Ave. S.	$3.50 to $6.00	$7.00 to $9.00
Hotel Sheraton	111 East Avenue	$3.65 to $6.15	$6.50 to $8.00

As this issue of Industrial Quality Control goes to press, final arrangements to round out the program are nearly complete. Final and full details will be mailed to all members of the Society in the form of a folder announcement as soon as the necessary information becomes available. The program as given herewith indicates clearly a range of topics and speakers that challenges attention.

General Theme: "QUALITY CONTROL IN THE COMING BUYER'S MARKET."

Place: Rochester Chamber of Commerce, 55 St. Paul Street, Rochester, New York.

Monday, February 16, 1948

10:00 A.M.

Registration—Lobby

All members and guests attending the Convention or any of its sessions are urged to register at Convention Headquarters in the Lobby of the Chamber of Commerce immediately upon arrival, even though they may have secured their Convention tickets in advance.

10:30 A.M.

Committee Meetings—ASQC
Gage Exhibits—Small Hall

12:15 P.M.

Luncheon—Grand Hall

SUBJECT: "Management Evaluates Progress in the Quality Control Field"

SPEAKER: Mr. Lee McCanne, Vice-President and General Manager, Stromberg-Carlson Company, Rochester, New York.

2:30 P.M.

General Session—Grand Hall

(1) SUBJECT: "Quality Control and Purchasing"
SPEAKER: Mr. Stuart F. Heinritz, Editor of the magazine "Purchasing," New York City, New York.

(2) SUBJECT: "Quality Control and Manufacturing"
SPEAKER: Mr. Phillip Bowman, Vice-President in charge of Plants, Bristol Laboratories, Syracuse, New York.

4:00 P.M.

Gage Exhibits—Small Hall
Board of Directors Meeting, ASQC

6:15 P.M.

Second Annual Convention Dinner, ASQC—Grand Hall

SUBJECT: "Quality Control Shows the Way"
SPEAKER: Dr. A. E. R. Westman, Director, Department of Chemistry, Ontario Research Foundation, Toronto, Canada.

Tuesday, February 17, 1948

9:00 A.M.

General Session—Grand Hall

(1) SUBJECT: "Quality Control and Sales"
SPEAKER: Mr. William Kerr, Sales Manager, Instrument Division, American Optical Company, Southbridge, Massachusetts.

(2) SUBJECT: "Quality Control and Engineering"
SPEAKER: Mr. Joseph Manuele, Director of Quality Control, Westinghouse Electric Corporation, East Pittsburgh, Pennsylvania.

10:30 A.M.

Gage Exhibits—Small Hall
Board and Committee Meetings, ASQC

12:15 P.M.

Luncheon—Grand Hall

SUBJECT: "Quality Control in Industry During the Post-War Period."
SPEAKER: Dr. Hugh M. Smallwood, Member-of-Staff, General Laboratories, United States Rubber Company, Passaic, New Jersey.

2:30 P.M.

Clinical Sessions—Room assignments will be given in the Convention Program, and will be posted at Convention Headquarters in the Chamber of Commerce.

CLINIC 1

SUBJECT: "The Plant Organization Required for Quality Control"
SPEAKER: Mr. Paul Robert, Quality Control Division, International Business Machine Corporation, Endicott, New York.

CLINIC 2

Cancelled

CLINIC 3

SUBJECT: "Inspecting Inspectors—A Psychological Testing Program"
SPEAKER: Dr. Leo Smith, Director of Counciling Center, Rochester Institute of Technology, Rochester, New York.

CLINIC 4

SUBJECT: "Quality Control Training Programs in Education and Industry"
SPEAKER: Mr. Edward Reynolds, Research Associate, Syracuse University, Syracuse, New York.

CLINIC 5

SUBJECT: "Quality Control in the Smaller Factory and Job Shop"
SPEAKER: Mr. D. Larmonth, Quality Director, Walz and Krenzer, Incorporated, Rochester, New York.

CLINIC 6

SUBJECT: "Statistical Quality Control—Practically"
SPEAKER: Mr. Walter Oliver, Assistant Quality Control Manager, Timken-Detroit Axle Company, Detroit, Michigan.

CLINIC 7

SUBJECT: "Latest Developments in the Gaging Field"
SPEAKER: Mr. J. A. Harrington, Chief Engineer, Doall Company, Minneapolis, Minnesota.

CLINIC 8

SUBJECT: "The Mechanics of How Quality Control Can Solve Purchasing and Vendor Relation Problems."
SPEAKER: Mr. Dorian Shainin, Chief Inspector, Hamilton Standard Propellors, East Hartford, Connecticut.

CLINIC 9

SUBJECT: "Chemistry Finds Uses for Quality Control"
SPEAKER: Dr. Everett V. Lewis, E. I. DuPont de Nemours Company, Wilmington, Delaware.

CLINIC 10

SUBJECT: "Quality Reports to Management"
SPEAKER: August B. Mundel, Chief Engineer, Quality Control and Inspection Division, Sonotone Corporation, Elmsford, New York.

CLINIC 11

SUBJECT: "Control Efforts in Proportion to Control Needs"
SPEAKER: Warren Purcell, Manager, Quality Control Department, Lamp Division, Sylvania Products, Incorporated, Salem, Massachusetts.

CLINIC 12

SUBJECT: "Consumer Pressure and Its Effect on Management and Quality Control"
SPEAKER: Dr. W. R. Pabst, Navy Bureau of Ordnance, Quality Control Division, Washington, D. C.

2:30 P.M.
Advertising Committee Meeting —ASQC

4:00 P.M.
Gage Exhibits
Committee Meetings—ASQC

5:00 P.M.
Adjournment

VISIT THE GAGE EXHIBITS

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Detection of Non-Random Variation When Size of Sample Varies

ACHESON J. DUNCAN
THE JOHNS HOPKINS UNIVERSITY

It is the purpose of this paper to discuss some of the problems that arise in the use of control charts when the samples employed vary considerably in size. In particular, it is argued that runs up and runs down, and cyclical movements in quality, cannot be properly detected on such a chart. As a means of meeting these difficulties, the proposal is made that the vertical scale on control charts be laid off in standard deviation units, or when that is unsatisfactory, that the vertical scale be made to measure the probability of a sample of equal or poorer quality. For p-charts, it is suggested that use be made of binomial probability paper.

Before developing the argument in detail, it must be emphasized that the quality control engineer should make every effort to obtain equal or approximately equal size samples. If that is not feasible, he should try to obtain samples that may be broken down into sub-samples that are of approximately the same size. It is only when all efforts of this kind have been unavailing, that the engineer has to face the problems that arise from unequal size samples.

If the size of sample does not vary, the limits on the ordinary control chart are constant. On such a chart, lack of control is indicated by points outside the control limits or by non-random variation within the limits. The former are designated "high spots" or "low spots" and are the evidence of lack of control most commonly looked for. Non-random variation within the control limits may take the form of (1) cyclical movements in the plotted points, (2) a bunching of the points near the upper and lower control limits, (3) a long run above average or a long run below average, and (4) a long run up or a long run down.

Cyclical movements refer to patterns of upward and downward movements in the data that tend more or less to repeat themselves. On a fraction defective control chart, for example, the values .09, .10, .11, .08, .07, .09, .11, .10, .07, .09, .12, .11, .06, .09, .13, .12, .10 would constitute a cylical movement. Such movements may generally be detected by an examination of the control chart.

Bunching near the control limits means greater concentration near the edges of the control chart than in the center. If the control limits of a fraction defective control chart were .14 and .01, the values 11, .12, .05, .10, .13, .11, .04, .03, .12, .02, .05, .03, 07, .11, .10 would illustrate a bunching of points near the control limits. Such bunching is usually detected by an examination of the control chart.

Runs above and below average and runs up and down may be illustrated as follows. If the average of a control chart is .07, then the values .10, .11, .09, .11, .10, .13, .12, .08, .09 would constitute a run of 9 above average and .06, .05, .04, .05, .06, .06, .05 would constitute a run of 7 below average. A succession of values such as .05, **.04, .06, .07, .09, .11, .12, .13,** .11 would constitute a run of 6 successive increases, and the values .10, **.12, .11, .09, .08, .06, .05, .04, .03,** .05 would constitute a run of 7 successive decreases The first is called a run up of 6 and the second a run down of 7. A run of 9 or more above or below the median, or a run up or a run down of 8 or more is considered as evidence of lack of control.[1]

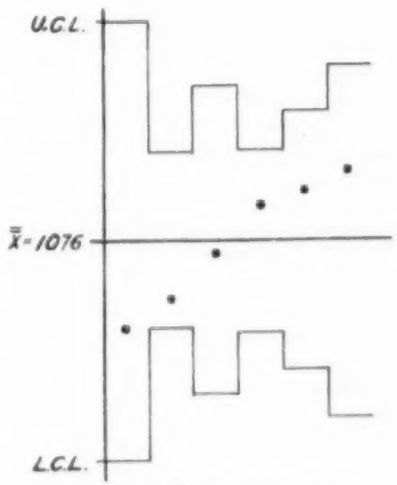

Figure 1—$\bar{X}$—CHART WITH VARIABLE LIMITS

If the size of sample varies, the limits on the ordinary control chart will also vary. (See, for example, Figure 1.) On such a chart high spots and low spots and runs above and runs below average will continue to be indicators of lack of control just as on a control chart with constant limits. There is a question, however, whether a control chart with variable control limits is a proper instrument for detecting cyclical movements or runs up and down in quality. Statistical theory says that there will be greater variability in a sample statistic if the sample is small than if it is large. Hence, if samples vary greatly in size, sample to sample comparison

1. Cf. Eugene L. Grant, *Statistical Quality Control*, p. 247 and P. S. Olmstead, "Distribution of Sample Arrangements for Runs Up and Down," *Annals of Mathematical Statistics*, Vol. 17 (March, 1946), pp. 24-33.

does not appear to be justified. Certainly it does not seem sound to try to detect cyclical movements or runs up or runs down in quality where the potential variability of the statistic used to measure quality is different from sample to sample. Variable control limits do not change bunching, but it may be more difficult to detect if the limits vary widely.

The problems that thus arise in the use of the ordinary control chart when samples vary considerably in size may be met by a reexamination of the statistical procedure for measuring variation in quality. To the writer the proper method of measuring changes in quality is to compare the probabilities of the sample deviations. To put it another way, a process may be said to be under control only if the variability of a sample statistic in samples of constant size adheres to an unchanging probability distribution. If the distribution of a selected sample statistic varies with the size of the sample, then when varying size samples are inspected, a new statistic whose distribution is independent of the size of the sample should be employed. This will give a distribution which will make it possible to compare sample variations. If it is not possible to find such a statistic, then the control chart should be set up directly in terms of probabilities.

This recommended procedure will now be discussed with reference to particular cases. Suppose first that the distribution of the sample statistic X can be approximated by the normal distribution. Then the statistic that will be independent of the size of the sample is $(X-\overline{X})/\sigma$, or the deviation of the sample statistic from its mean value divided by its standard error. In essence this means that when the distribution of the sample statistic is normal or approximately normal, the control chart that will properly depict cyclical movements and runs up and runs down is one on which the sample variations are measured in standard deviation units.

To illustrate, suppose that a process has a mean of 1076 and a standard deviation of 20, and that variability appears to be normal. On the ordinary control chart, the statistic plotted would be the sample mean. The central line would be at 1076 and the limits would be given as a function of sample size as follows:

$$UCL = \overline{\overline{X}} + 3\sigma/\sqrt{N}$$
$$= 1076 + 60/\sqrt{N}$$
$$LCL = \overline{\overline{X}} - 3\sigma/\sqrt{N}$$
$$= 1076 - 60/\sqrt{N}$$

On the recommended control chart making use of standard deviation units, the statistic plotted on the chart would be $\frac{\bar{x}-\bar{\bar{x}}}{\sigma/\sqrt{N}}$, the central line on the chart would be at zero, the upper control limit at 3 and the lower control limit at −3. This modified chart could be called an $\overline{X}_\sigma$—chart to distinguish it from an ordinary $\overline{X}$— chart.

To show how a run up on one chart might not be a run up on the other, suppose the following six samples were taken:

Sample	N	$\overline{X}$
1	10	1069
2	70	1071
3	20	1075
4	60	1079
5	30	1080
6	15	1082

On an ordinary $\overline{X}$— chart with variable control limits, these sample means would appear as in Figure 1.

For the given data the statistic $\frac{\bar{x}-\bar{\bar{x}}}{\sigma/\sqrt{N}}$ would have the values:

Sample	$\frac{\bar{x}-\bar{\bar{x}}}{\sigma/\sqrt{N}}$
1	−1.11
2	−2.50
3	− .22
4	1.16
5	1.09
6	1.16

which when plotted on an $\overline{X}_\sigma$— chart would look as shown in Figure 2.

It is seen immediately that on the ordinary $\overline{X}$— chart the sample means show a run up of 5. On the $\overline{X}_\sigma$— chart, however, no such run appears. It should be clear that the reverse might also be true. A run up or down on the $\overline{X}_\sigma$— chart might not appear as a run on the ordinary $\overline{X}$— chart. Since the $\overline{X}_\sigma$— chart, it is contended, is the proper one for showing true runs in quality, the ordinary $\overline{X}$— chart with variable control limits should not be used for that purpose. It should also be clear that a cyclical movement on an $\overline{X}_\sigma$— chart might be so distorted on an $\overline{X}$— chart with variable control limits as to be unrecognizable.

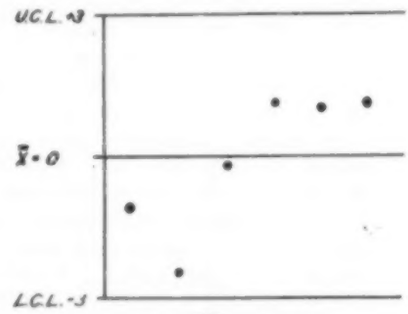

Figure 2—$\overline{X}_\sigma$—CHART

That $\overline{X}_\sigma$— charts would require more work on the part of the operating staff is not denied. The amount of the extra work, however, would not be very great. The quality control office could prepare a table of values for $\sigma/\sqrt{N}$, using the standard deviation of the process and expected values of N. The man who maintains the control chart would thus need only to subtract the mean calculated for each sample from the stated process mean and divide by the value of $\sigma/\sqrt{N}$ given by the table. If the control chart man knows how to use a slide rule, the extra work required would be very slight.

It might be noted that $\overline{X}_\sigma$— charts with their constant limits would be a better form to present to management, and would probably raise less questions from all sources than do $\overline{X}$— charts with variable control limits. If it is believed that the use of standard deviation units might be confusing, it would be possible to use a scale based on percentages of 3σ. In other words, instead of using the statistic $\frac{\bar{x}-\bar{\bar{x}}}{\sigma/\sqrt{N}}$, one could use $\frac{\bar{x}-\bar{\bar{x}}}{3\sigma/\sqrt{N}}$.[1] The control limits in this case would be +1.00 and −1.00, intermediate points would run .72, −.53, .42, etc., and high spots and low spots would be shown by values numerically greater than 1.00. Such a chart is illustrated in Figure 3. It may be considered a special version of an $\overline{X}_\sigma$— chart.

1. This suggestion was made to the writer by Mr. B. L. Sander of the Bendix Radio Division of the Bendix Aviation Corp.

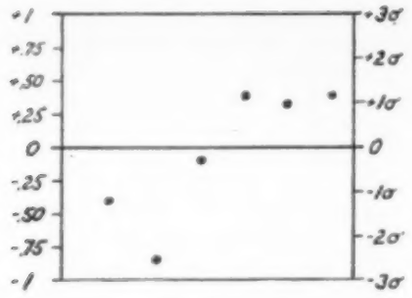

Figure 3—$\bar{X}_\sigma$—CHART ON PERCENTAGE BASIS

The foregoing illustration pertains to a control chart for variables. Consider now a control chart for fraction defective. If $\bar{p}$ is the estimate of the process average, and if $\bar{p}$ is greater than .10, so that the normal distribution is used in setting up control limits, then these limits would be

$$UCL = \bar{p} + 3\sqrt{\frac{\bar{p}(1-\bar{p})}{N}} \quad ; \quad LCL = \bar{p} - 3\sqrt{\frac{\bar{p}(1-\bar{p})}{N}} \ .$$

If, as before, the size of the sample varies considerably, the control limits on a p- chart would also vary considerably. As in the case of variables, it may be contended that such a chart would not properly show cyclical movements or runs up or runs down. The recommended procedure is to use a control chart showing the statistic $\dfrac{p-\bar{p}}{\sqrt{\frac{\bar{p}(1-\bar{p})}{N}}}$, (i.e. sample percentage p, minus the process average $\bar{p}$, divided by the standard deviation of the sample percentage). Such a chart would have a mean of zero and constant control limits of +3 and −3. For brevity it may be called a $\bar{p}_\sigma$ chart. If units of 3σ are employed instead of σ, the proper statistic would be $\dfrac{p-\bar{p}}{3\sqrt{\frac{\bar{p}(1-\bar{p})}{N}}}$, and the limits on the chart would be +1 and −1. A worksheet for the latter type of control chart is shown in Figure 4.[1] If 3σ values can be obtained from tables computed in the head office, the work of the operator will consist of elementary arithmetical computation.

A graphic method that might be even simpler and would involve no arithmetic computation is to use binomial probability paper. This is illustrated in Figure 5. On this paper the control chart office need only draw in the line representing the process average. The man who maintains the control chart would then have merely the job of locating the point whose ordinate is the number of defective units in the sample and whose abscissa is the number of non-defective units and then measuring the perpendicular distance from this point to the line representing the process average. (See Figure 5). This distance he could lay off on a control chart whose vertical scale was the standard deviation (σ) scale indicated on the binomial probability paper, or a scale that is 1/3 of this if 3σ units are used.[2]

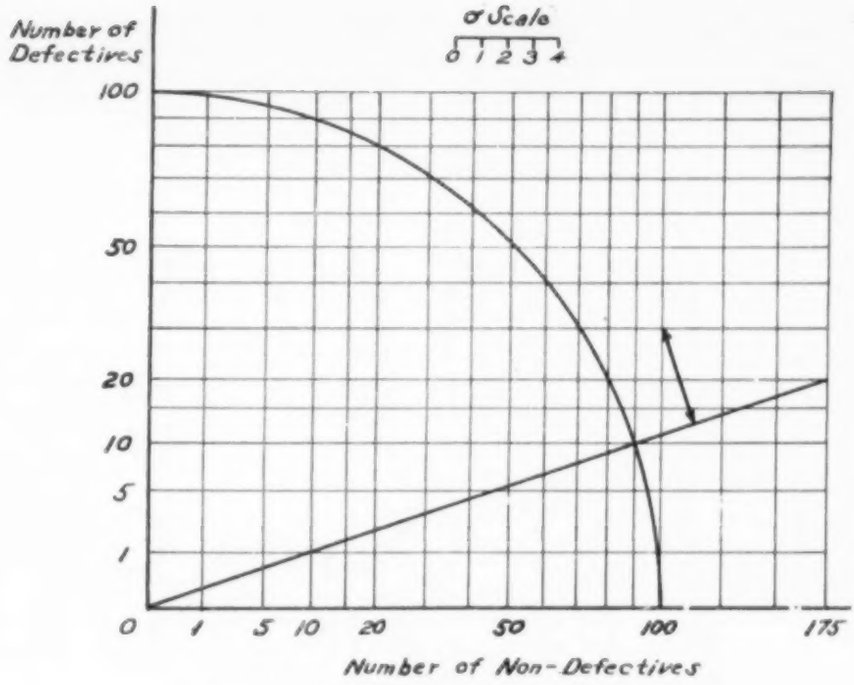

Figure 5—BINOMIAL PROBABILITY GRID

1. The design of this table was suggested to the writer by B. L. Sander of the Radio Division of the Bendix Aviation Corporation.

2. This method was suggested to the writer by Frederick Mosteller, Harvard University. Dr. Mosteller and Dr. Tukey are co-designers of binomial probability paper.

Q. C. Data Sheet

Dept. 4 — Part No. A-25349 — Description 100Ω Res $\bar{p}$=.10

Date	Sample Size (N)	No. Defective Found in Sample (n)	Fraction Defective $p = n/N$	Three Sigma $3\sqrt{\frac{\bar{p}(1-\bar{p})}{N}}$	Sample Deviation from Average Fraction Defective $(p-\bar{p})$	Plot Point $\frac{p-\bar{p}}{3\sqrt{\frac{\bar{p}(1-\bar{p})}{N}}}$
7/20	300	42	.14	.052	.14 − .10 = +.04	$\frac{+.04}{.052} = +.78$
7/21	1000	80	.08	.028	.08 − .10 = −.02	$\frac{-.020}{.028} = -.72$

Figure 4—WORKSHEET FOR p_σ—CHART

If p is less than .10, it is customary to use the Poisson distribution instead of the normal distribution to approximate the binomial distribution. Binomial probability paper, however, continues to give a reasonably good approximation to the binomial distribution for values as low as $\bar{p}=.01$ and samples as small as 50. In fact, the approximation is not bad for $\bar{p}=.01$ and samples as small as 5. In practice, then, where samples frequently run much larger than 50, binomial probability paper can be used with safety even for very low probabilities. It might be desirable in such cases, however, to "blow up" the paper to a larger size for practical use in the plant.

In conclusion, it might be noted that if samples are large and variable in size, the ordinary σ— chart should also be replaced by a chart which uses standard deviation units. The argument and procedure would be the same as that pertaining to an $\bar{X}$- chart with variable control limits. The only difference would be that σ would replace $\bar{X}$ and $\sigma/\sqrt{2N}$ would replace $\sigma/\sqrt{N}$. This modified type of σ-chart might be designated a σ_σ-chart. If the samples varied in size but were smaller than 30, a chart expressed directly in probabilities would afford the simplest procedure. Unfortunately, however, the chi-square tables from which the probabilities would have to be computed are not graduated sufficiently to make this a practical solution. Similar remarks would apply to R- charts.

Quality Control Proves Itself In Assembly*

WILBUR L. BURNS
HARRISON RADIATOR DIVISION, GENERAL MOTORS CORPORATION

SETTING

The term "Quality Control" is so broad that confusion is likely to arise unless the field of application is defined. At the Harrison Radiator Plants of General Motors the three major applications of quality control methods are:

1. Scientific sampling.
2. Control of direct measurements in the manufacturing process.
3. Identification of quality of manufactured products after fabrication or at various stages in the production process.

The latter, which will be discussed here, may be considered quality determination rather than quality control because little can be done to control or rectify the defects after they are found in the completed product, but the information obtained from such determination permits production departments to correct quality defects. In that sense, quality determination leads to quality control, and for that reason this field is one in which the Quality Control Department will almost certainly be called to work. This broader field not only must be considered, but it has proved itself in our assembly departments.

Quality control by statistical methods was first employed in our plant during World War II, as an aid in increasing the quantity of good quality material in order to meet the volume production required by the armed forces. It was found that the application of these methods not only increased production of good quality material, at the same time reducing scrap losses of scarce metals, but also resulted in an appreciable decrease in cost.

Realizing that quantity, quality, and costs are of as vital concern to the manufacturer under peacetime conditions as they were during the war, the need for quality control has increased, particularly in assembly departments which constitute a large portion of our operations. Statistical methods are used as a scientific technique for collecting and analyzing data, setting quality standards, and maintaining adherence to these standards.

In any program of quality control, it must be recognized that in quality as in everything else, there is a law of diminishing returns. As perfection is approached, cost of production often rises to disproportionate heights. Therefore, quality must be reconciled with a cost of production which permits quantity sales in a competitive market. The tool of quality control properly used in setting quality standards can be a great aid to management in maintaining a proper balance between quality, cost, selling price, and net profit.

The problem of quality control in our Thermostat and Radiator Assembly Departments is very similar to that of any other manufacturer turning out millions of the same kind of thing each year, whether it be flat irons, airplanes, or chocolate drops. We set up a quality standard in line with the law of diminishing returns, and then try to make all of the units to conform to this standard. Here our troubles begin.

The aim of the manufacturer is to reproduce the same kind of product again and again, but in the assembly of heat transfer units which requires the soldering of

* Paper presented at Clinic #16, Second Midwest Quality Control Conference, June 6, 1947. Not published in Conference Papers because manuscript not available when the book went to press.

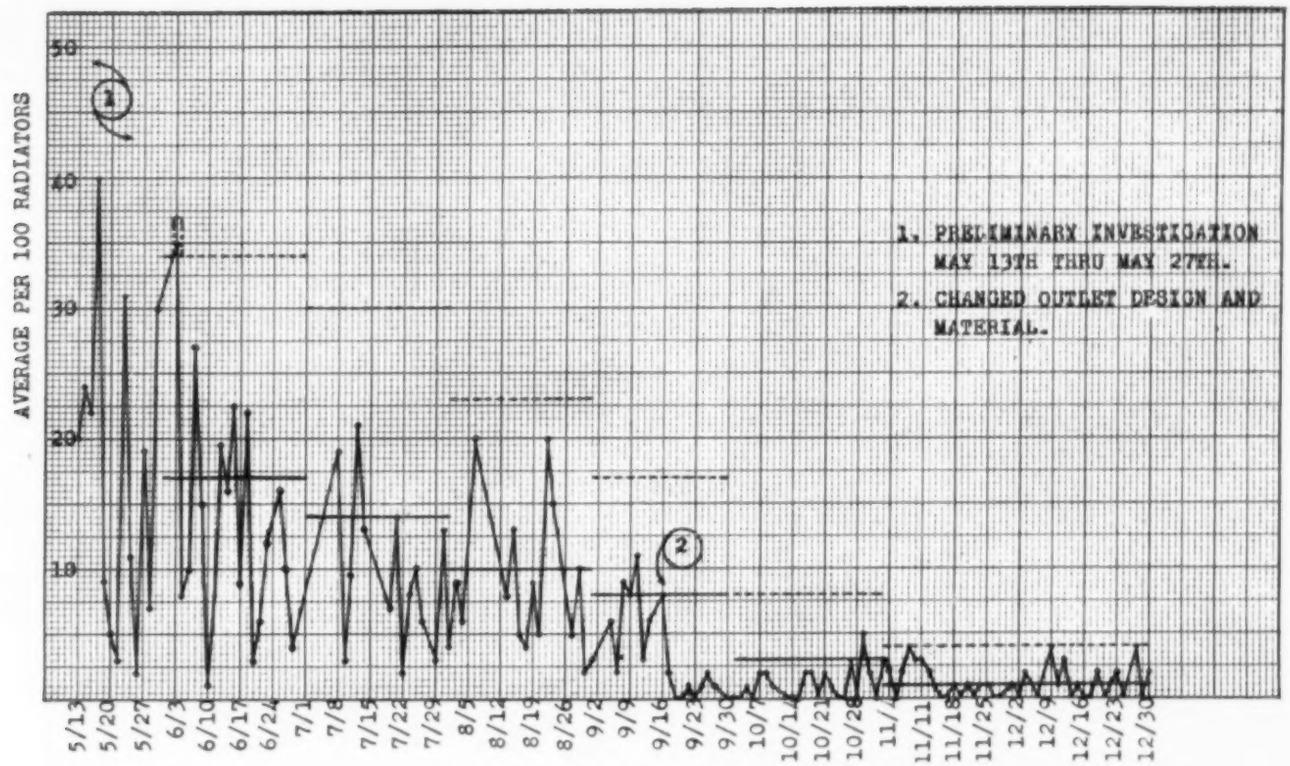

Figure 1 — RADIATOR ASSEMBLY — OUTLET LEAKS — MODEL R-200

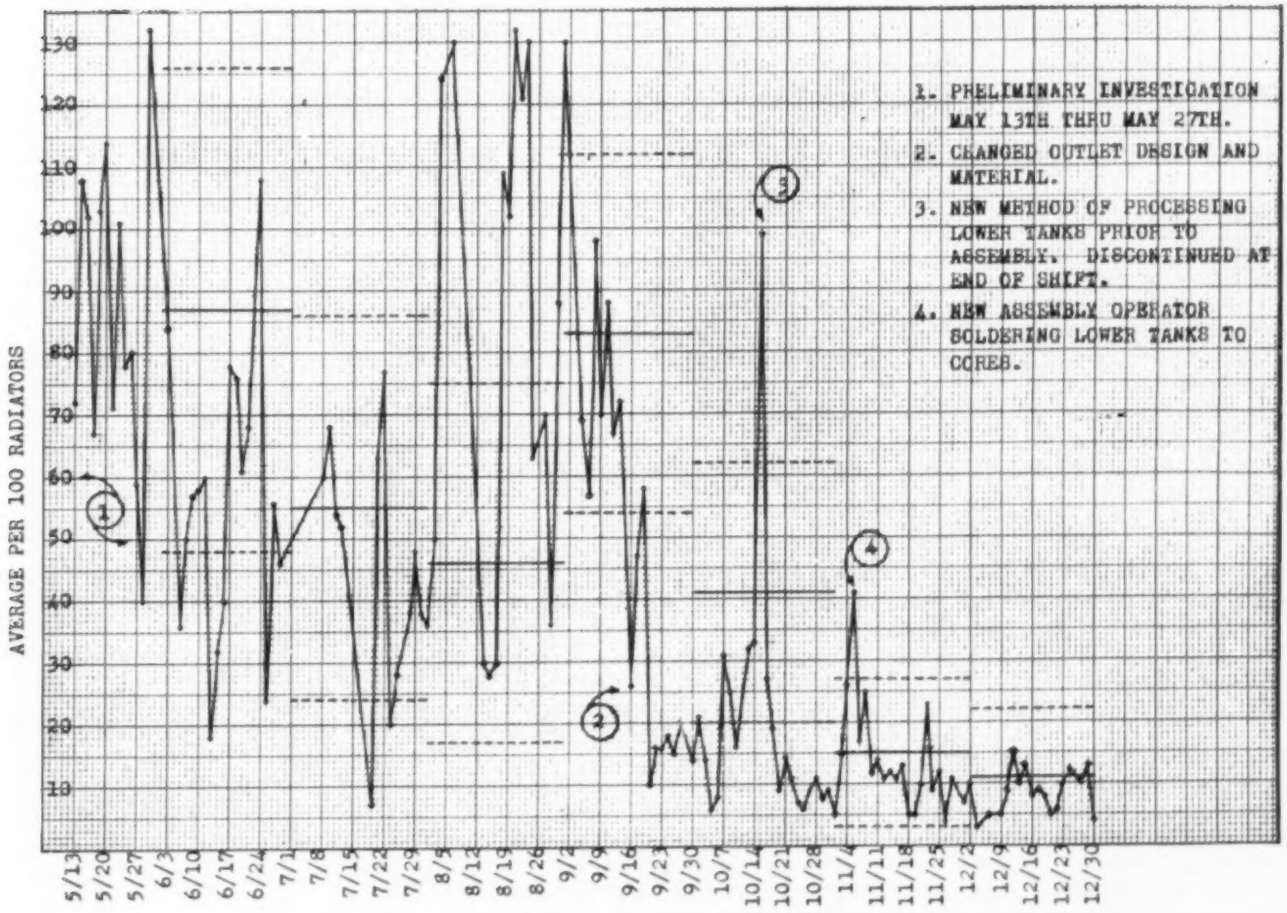

Figure 2 — RADIATOR ASSEMBLY — LOWER TANK REAR LEAKS — MODEL R-200

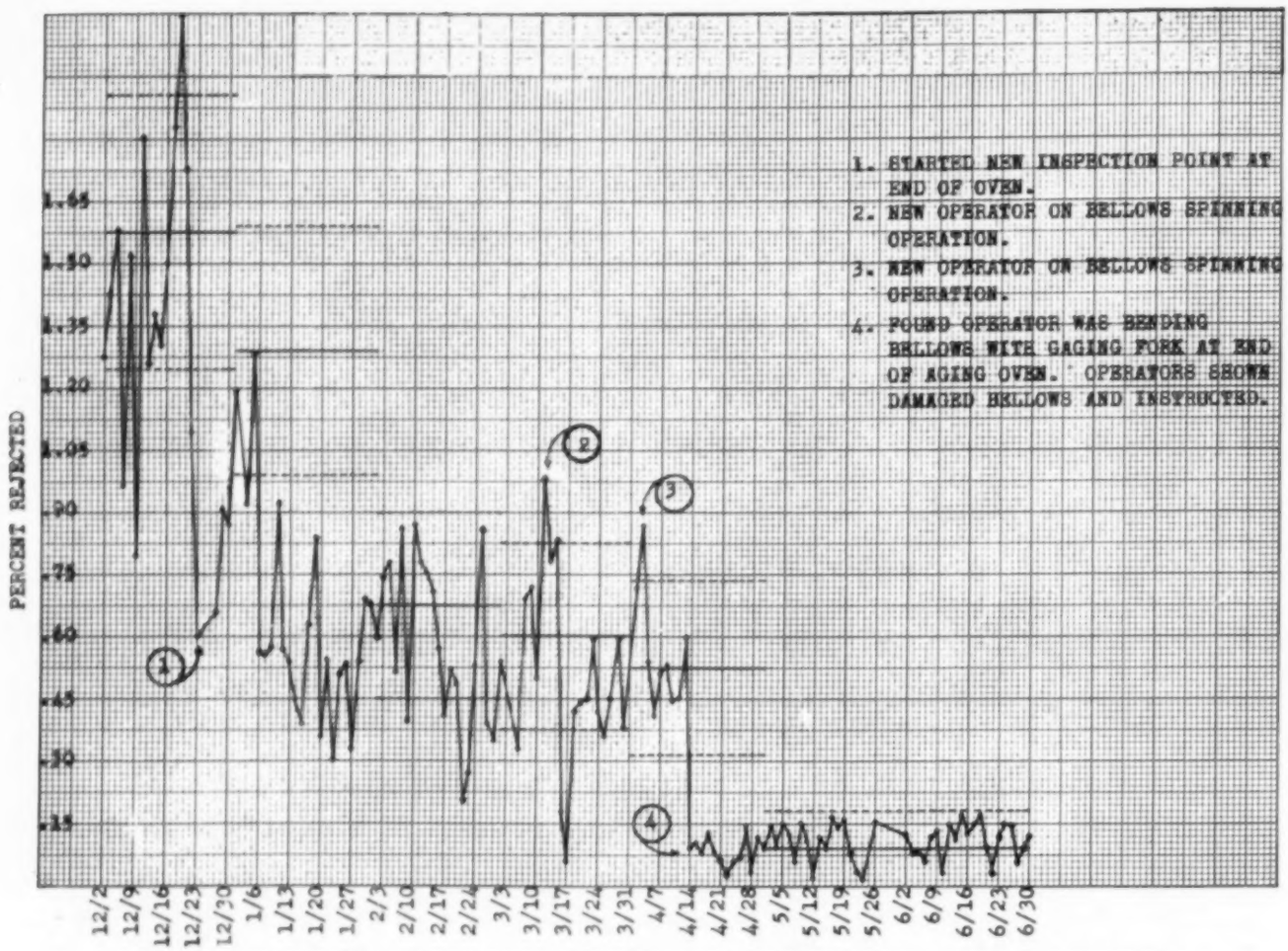

Figure 3 — THERMOSTAT ASSEMBLY — DEFECTIVE BELLOWS REJECTED AT FINAL INSPECTION

hundreds of water-tight joints, as in other fields, we know it is quite impossible to make two things exactly alike. Even with the best known means of regulating materials, production, machinery, and manual operations, we always find measurable differences in individual articles turned out by the production process. Therefore, one of the basic characteristics of quality is variability. This variability is something we can never get away from, but quality control methods will help in regulating and controlling it in assembly, from unit to unit, from machine to machine, from jig to jig, from operator to operator, from day to day, and so on.

Our problem then is: How much may the quality of a radiator or thermostat vary and still be controlled? In other words, how much variation between assemblies should be left to chance? A system of chance causes is present in any process, and variation within this system is inevitable. However, by the use of the control chart the presence or entrance of assignable causes for excessive variation can soon be recognized. The undesirable factors contributing to the cause for these out-of-control points may then be investigated and corrective measures taken to improve or eliminate them.

PROCEDURE

When inaugurating a quality control program in an assembly department, as well as in any other department, a thorough study of the entire process should be made. This study should include such items as sequence of operation, types of machinery, equipment, jigs, fixtures and gauges used, method, operator motion path, and facilities for disposal of good material and scrap or rework material. The location of inspection points and past inspection records should also be reviewed. Existing inspection records are often found to be inadequate due to being incomplete or inaccurate. It may also be necessary to check inspector variability which is prevalent in visual inspection as a result of the difference in judgment between inspectors. Only pertinent information should be recorded on inspection records, which are designed so that the data can be recorded with a minimum of effort and confusion by the inspector.

Upon completion of an analysis of the preliminary information (taken from either existing or new inspection records), frequency distributions, control charts, and any other information relative to the assembly should be worked up along with an outline of the proposed plan for approaching the problem, and presented to upper management for approval.

Quality control without corrective action is sterile. Therefore, after obtaining approval of the

proposed program by top management, the next step of forming a Corrective Action Committee, and presenting this preliminary information to them at the beginning of a control program, is very important. At Harrison, the nucleus of the Corrective Action Committee, of which the Quality Control Engineer is chairman, is composed of the Production Superintendent of the plant involved, the Production Foremen and Inspection Foremen concerned, the Project Engineer, and a representative of the Methods Department, the Tool Department, and the Field Service Department. Other members of management may be called in from time to time as necessary. At the first meeting of this committee the major point of trouble, as revealed in the preliminary investigation, is selected for discussion, and after considering all contributing factors, a plan of corrective measures is developed and agreed upon.

Quality charts for applicable conditions are then placed as near as possible to their respective operations in the assembly department. From the viewpoint of securing the most effective use of quality control methods in a manufacturing plant, each application should be tailor made for its particular circumstances, and of course the type of chart used will depend upon the kind of product, operation, or variable to be controlled. At each Corrective Action Meeting, the charts for operations that show lack of control are reviewed and discussed. The committee then investigates to determine what action is necessary to bring the operation into control. Progress reports of all corrective measures taken are made to the committee at subsequent meetings. It is also the responsibility of the chairman of the committee to send a summary report of each meeting to all members of the committee and to members of management immediately after each meeting.

The charts are plotted immediately after the end of the shift each day. Points falling outside the control limits are jointly investigated by the Quality Control "trouble shooter" and the Production Foreman concerned. Their findings and corrective measures taken are recorded on a "high point" report, copies of which are sent to the Production General Foreman and the Inspection General Foreman daily, so that they know of the points causing trouble, and also what is being done about them. (The lines of authority and responsibility at Harrison run through the Superintendent, General Foreman, and the Department Foreman.)

ILLUSTRATION A — RADIATOR

The inspection data converted to chart form not only give a graphic picture of the quality of the assembly operations, but tend to focus attention on the troublesome points. The charts also stimulate thinking for corrective measures. Figure 1* illustrates how one change reduced the number of repairs after assembly. As a result of the attention the quality record focused on outlet leaks at the end of the assembly line, the Superintendent of our Standards and Methods Department suggested that the design and material be changed. In addition to the material and labor savings resulting from this change, the quality record indicated a considerable reduction in leaks; therefore, it was quickly approved for all models.

Figure 2 shows how a change in one operation may affect another assembly operation. In this particular instance, there was considerable variation in the number of leaks found on the rear side of the lower tank-to-core joint after assembly. Investigation revealed that the high degree of heat required for assembling the outlet into the tank was disturbing the solder joint of this previous operation. The material change required much less heat for outlet assembly, and the lower tank rear assembly was also brought into control.

Quality control undertakes to build quality into a product rather than attempting to accomplish the quality objective through futile and costly inspection. In the past, many disagreements between Engineering, Inspection, and Production were due to the absence of facts in a form that would provide a basis for agreement. In many cases, the Quality Control records now provide the necessary information which is used by all groups in arriving at a rational solution of many of their mutual problems. By tabulating, summarizing, and making chain use of the data obtained at inspection points in the assembly process or at the end of the assembly line, we readily get a running picture of events at each assembly operation. By properly analyzing this picture, we can also get the answers to some of the questions that are of importance to those responsible for shop performance. A foreman in our Thermostat Department says that he often uses the record of the Quality Control Chart to point out the need for such things as redesigned assembly fixtures, machine maintenance, or changes in manufacturing tolerance. Another foreman says that when he is trying to get an idea accepted, he often gets acceptance on the basis that the Quality Control Charts will show its merits or demerits. If the quality record shows an improvement, the idea usually is accepted, and if the quality record shows poorer quality or more rejections, he himself, doesn't want the change.

ILLUSTRATION B — THERMOSTAT

In our Thermostat Department, the percentage of completed thermostats rejected for defective bellows at final inspection appeared too high, as indicated in Figure 3. An analysis of the quality record showed that at this level of rejection it would be more practical to place an inspection point at the beginning of the process to sort out the defective bellows, instead of letting them get through to assembly, only to have the completed thermostat rejected at final inspection. The new inspection point resulted in a 1% reduction in rejections at final inspection, afforded closer control at the bellows assembly operation, and also brought to light the fact that approximately .6% of the rejections were due to damage occurring in the assembly process. After considerable investigation, it was found that the operator had a tendency to bend the bellows in one of the assembly operations. When this was corrected, rejections for defective bellows were immediately brought into control at a new low rejection level. Without the addition of the new inspection

*Average lines and control limits in Figures 1 and 2 have been computed as explained in the appendix, and for each month are a projection of the previous month's experience.

point to assure good bellows assemblies going into the process, the damage occurring in the assembly operation probably would not have been detected.

MANAGEMENT CHARTS

In the continuous manufacture or assembly of any type of product, management often wishes to know the answer to such questions as: How good is the quality of current production? Is it as good as it should be? Is it better or poorer than last week? How are we doing compared with six months ago? Therefore, no quality control program is complete without periodic quality progress reports to upper management. Figure 4 illustrates a simple graph showing the overall quality for a given product; this graph is sent to upper management and members of the Corrective Action Committee weekly. This type of routine report may also be supplemented occasionally with other reports that are of interest to management, such as the Frequency Distribution shown in Figure 5.

Quality control is not to be mistaken as a cure-all, but it has created and maintained an excellent psychological effect in keeping everyone at Harrison conscious of quality workmanship by showing the quality level being maintained and helping to fix responsibility for low quality workmanship. Right now, quality counts in a big way, and it must be maintained by close control carefully handled by each person responsible for getting out the work. The first thing that many of our Production Foremen do when receiving a new employee is to take him to the Quality Control Board and explain how the chart gives a running picture of the quality of the operation on which he is going to work.

In quality control as in any other activity requiring cooperation among departments, the question may arise as to who should get the credit for savings from quality improvements. Arguing this question is as futile as arguing the question of what individual player won a football game. Any quality improvements made by diagnosing troubles, indicated by the quality control charts, are necessarily based on team work. Inspection personnel, production personnel,

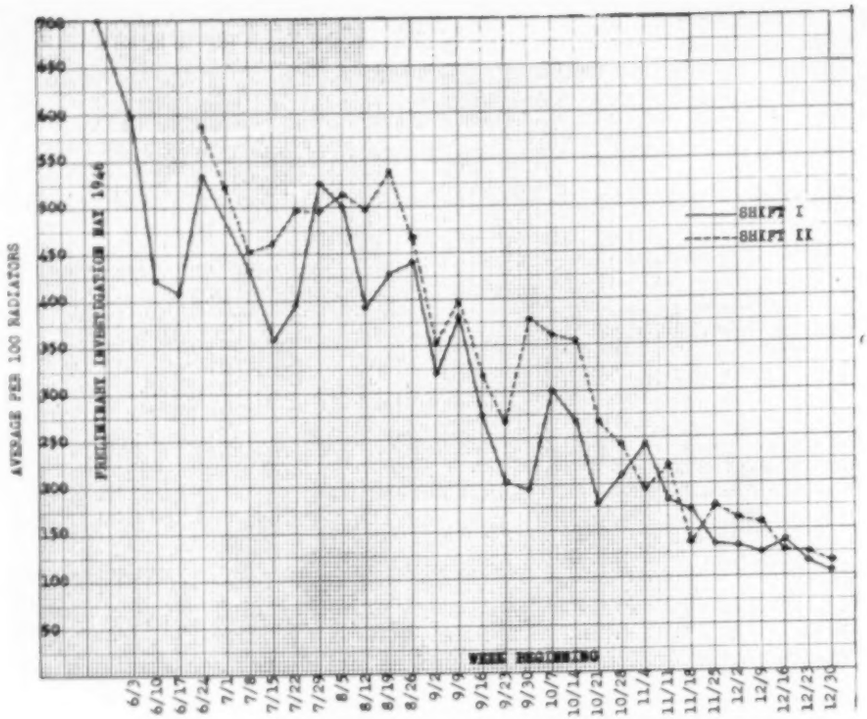

Figure 4 — QUALITY INDEX AND PROGRESS RECORD

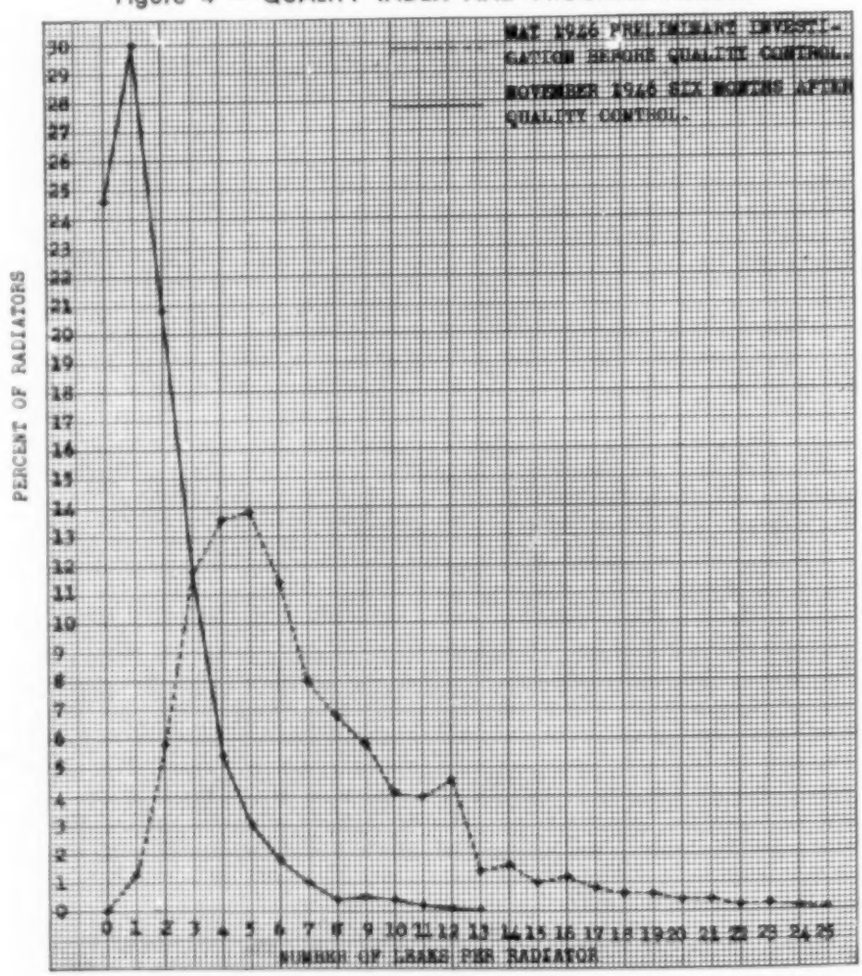

Figure 5 — DISTRIBUTION OF RADIATOR LEAKS AT TEST AND REPAIR, MODEL R-200

methods engineers, tool engineers, product engineers and others, all participate. From the standpoint of management, the important question is not who gets the credit, but rather what savings are we making, and what quality improvements are we getting, by using this tool of quality control, that were overlooked previously?

CONCLUSION

Since the installation about a year ago of quality control techniques in our assembly departments, a large reduction in costs has been made through:

1. More uniform work at higher quality standards.
2. Reduced repairs, salvage, and scrap.
3. Improved inspection and production methods.
4. Higher production of good assemblies per man-hour.
5. Better plant relations which have grown out of the coordination work of the Quality Control Department.

It should be recognized that the activities of the Quality Control Department must have the support of top management, but even so, the Quality Control Engineer should not depend upon this support for acceptance of his program. For the most satisfactory results, there must be a spirit of cooperation all along the line which will come in a considerable measure from the manner of persuasion and diplomacy used, and the ability to get along with people on the part of those in the Quality Control Department. The Quality Control Engineer must possess imagination and ingenuity, as well as the courage of his own convictions. He cannot be merely a yes man, but at the same time the production foremen who are there on the firing line each day must be made to feel that Quality Control is a device to help them rather than police them. The quality control operator should always remember that the original source of most of his information must usually come from the processing or assembly area.

Quality Control techniques can be effectively used in practically all departments of a manufacturing plant where variation in some form is sure to exist. Wherever variation is present, statistical control will be helpful. Based upon the daily determination of quality at the end of the radiator assembly lines, our Standards Department is successfully applying time study values and setting production rates of pieces per hour on certain operations.

At Harrison, Statistical Quality Control is an effective industrial tool for maintaining the thought expressed in the slogan "Quality is remembered long after the price is forgotten."

APPENDIX

Formula for computing control chart limits.*

c = Number of leaks in daily sample.

u = Number of radiators in the sample.

$100(c/u)$ = Average number of leaks per 100 radiators. (This point is plotted on chart.)

$100(c/u)'$ = Monthly average of leaks per 100 radiators.

CONTROL LIMIT FORMULAS

$$UCL/100 = (c/u)' + 3\sqrt{(c/u)'}/\sqrt{u}$$

$$LCL/100 = (c/u)' - 3\sqrt{(c/u)'}/\sqrt{u}$$

Calculation of center line and control limits is shown below for July based on the June record. (See accompanying table and Figure 1). For July, u is estimated as 50.

$$100(c/u)' = (100)(116)/841 = 14$$

$$UCL = 14 + 300\sqrt{.14}/\sqrt{50} = 30$$

$$LCL = 14 - 300\sqrt{.14}/\sqrt{.50} = 0$$

* Grant, E. L., "Statistical Quality Control," McGraw Hill Book Co., New York, 1946, pp. 304-305.

Outlet Leak Record for June

Date	No. Tested u	No. of Leaks in Sample c	Av. Per Rad. c/u	Av. Per 100 Rads. $c/u \times 100$
6/3	39	14	.35	35
6/4	45	4	.08	8
6/5	46	5	.10	10
6/6	48	13	.27	27
6/7	40	6	.15	15
6/10	58	2	.03	3
6/11	50	4	.08	8
6/12	50	11	.22	22
6/13	50	8	.16	16
6/14	50	10	.20	20
6/17	32	3	.09	9
6/18	50	11	.22	22
6/19	33	1	.03	3
6/20	50	3	.06	6
6/24	50	6	.12	12
6/25	50	8	.16	16
6/26	50	5	.10	10
6/27	50	2	.04	4
Total	841	116		

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Use of Statistical Methods for Time Study of Batch Processes*

W. S. TRAYLOR
HERCULES POWDER COMPANY, MANSFIELD, MASSACHUSETTS

ABSTRACT

Industries using batch processes, where large investments are involved in processing equipment, need a system for intimate time study of individual phases affecting the total processing time to assure maximum production per machine-hour. The arithmetic average of the total time consumed in processing a series of batches has been used, but this does not give the complete story of the operation. The statistical method of time cycle control provides a means for arranging various phases affecting the operation for individual study.

Establishing the studies required in the investigation and the methods used in assimilating the data for plotting the charts are important steps in the successful use of the system. By using statistical methods to study the production in a previously assumed efficient operation, a general time reduction of ten to twenty percent was realized in the processing cycles.

THE REASONS FOR TIME STUDY

In industries where batch processes are used, the cooking cycle of the batch, or the processing time, is second only to quality in importance. An intimate study of the phases affecting the processing time is the only means by which the efficiency of the operation can be determined.

An increase in production per man-hour or machine-hour is recognized as the best method available to industry for reducing cost. This increase for batch processes can be accomplished by several methods using one or more, or all, of the following devices:

(1) Improvement in formulation
(2) Improved machine design
(3) Improved operating technique.

Even though all these devices and others may be installed to improve the efficiency of an operation, there can be no guarantee that maximum efficiency is being obtained unless there is an accurate method of measuring changes in time intervals. Development and maintenance of an efficient operation depends upon establishing an hour by hour, day by day, and month by month method of measuring the performance against time, and organizing the resulting data for comparative study. Sudden bursts of efficiency for short intervals in production drives cannot be accepted as good operations. Such drives are usually of short duration, and results are quite often obtained through a sacrifice of quality, morale, and machines. The real measure of plant efficiency is a stable day by day average performance showing improvements that can be measured and maintained.

Heretofore it has been difficult for the production man using a batch process to measure the efficiency of his plant in relation to average time cycles. He has made use of arithmetic averages, but the arithmetic average of the total time consumed in processing does not give a complete picture of the operation. It does not take into consideration the range within which all accurately processed batches can be expected to fall. The arithmetic average is not specific, for it does not indicate at what point in the process time is saved or time is lost. When the operator draws a conclusion regarding the efficiency of the operation, he can assume only that a cycle time less than the arithmetic average is just good fortune, and consider that a cycle time greater than the arithmetic average is lost operating time, usually with no cause assignable for the lost time or the improvement as the case may be.

The introduction to industry of control by statistical methods provides the production man with a tool well-adapted for measuring the efficiency of the plant through time study, and enables him at the same time to keep a permanent record of the operation. There is no limit to the number of phases of the operation that can be studied individually by this method.

Time cycle control, or study, of batch processes by statistical methods has been used in the Mansfield Plant of Hercules Powder Company since January, 1947, with some very interesting and profitable results. It is important to note that this time study was made in a plant fitted with new equipment, where the best in machine design had been installed, where the best known operating techniques were applied, and where the process had been improved by research to such a point that improvements in operating procedures had reached a stalemate. The cycle time of the process involved in the study had previously been reduced 50% through the use of improved equipment and operating techniques. Thus, the operation was one which outwardly appeared to have reached maximum efficiency. Cycle times had been reduced to a point where minutes, not hours, were important.

The results from a study made on two processing vessels or kettles of identical design and method of heating will be discussed and illustrated on charts. Eleven related products were produced in the vessels. By using statistical methods to study the production of all these products, a general time reduction

*Presented at a meeting of the Boston Section ASQC, October 15, 1947.

of ten to twenty percent was realized in the processing cycles.

SETTING UP TIME CYCLE CONTROL STUDY

The successful use of statistical methods for time cycle control depends entirely on setting up the job correctly. Each study must represent a phase of the operation or a group of phases that may be easily segregated for analysis. Combining studies to reduce charting is limited and may be practiced only to the extent that a given study does not lose its individuality, nor cease to be specific. In carrying out the plan at Mansfield, each cycle was broken down into the following studies:

1. Charging Time
2. Upheat Time
3. Holding Time
4. Total Time or Gross Time.

The "Charging Time" covered that phase of the operation from the time the last batch was discharged from the kettle until all ingredients had been charged for the next batch. Included in charging time were a number of operations the individual data for which were not plotted but were carried on the operating log sheets, and were available for study should the need arise to make a more thorough investigation. For example, the time required to load each raw material into the kettle was recorded, but data were not plotted individually.

Items which could influence charging time included the time taken to get the kettle back into operation (human factor), the performance of pumps and conveyor used in charging the raw materials (mechnical factor), the condition of the raw materials (viscosity, moisture), and the temperature of the kettle after all ingredients had been charged (human factor and boiler efficiency).

Naturally, it took some research to establish the time factor for each piece of equipment used in charging, but this was not a major problem requiring a lot of time. This information may usually be obtained with little effort as the job progresses. In cases where two identical pumps or other identical pieces of equipment are being used, relative efficiencies may be determined by comparing rates for the similar pieces equipment.

The second study, that of "Upheat Time" covered the period beginning with the time when the last raw material was charged to the kettle until the batch reached the top temperature at which it was held to complete the reaction. Unfortunately, upheat time could not be further broken down in time intervals for future study. Factors affecting upheat, then, had to be previously known or hunted out if valuable time was to be saved in this period of operation. Primarily, upheat time represented boiler efficiency or the rate at which the kettle was being supplied with heat. When upheat time showed a lag and needed investigation it called for a study of the boiler, and all auxiliary equipment, such as temperature recorders and automatic valves, that controlled heat or the rate at which heat was supplied to the kettle.

The third study of the processing cycle was "Holding Time" which covered the period of operation from the time the kettle reached top temperature until the reaction was completed and the product discharged from the kettle. This phase of the operation can be broken down further into time intervals which, though not charted individually, may be recorded on the log sheet for future reference. Factors affecting holding time are: accuracy of the temperature recorder, control samples, application of various processing techniques at the correct time and in the correct manner, and the discharge of the kettle when the reaction is completed.

The summarizing phase of the study, "Total Time", was the gross time of all the other studies. This is the part of the operation most interesting to management and the director of operations. It reflects the efficiency of the operation and might easily be the controlling factor between profits and losses. It is the summation of all the operating efforts. It gives the tell-tale results that cannot be changed for the better nor maintained without going through the previous tedious steps of studying the component parts of the total cycle.

This is the line of demarcation between arithmetic averages and statistical methods for use in time study. The arithmetic average gives only the gross time consumed in processing all batches. The statistical method of time cycle control provides a means for averaging individual data on various phases affecting the operation so that they can be segregated for careful analysis.

It will be discovered in setting up a time study that one does not know or is not conscious of all the variables in the operation. This should not be discouraging, for it will be surprising, once the studies are established, how easily previously unrecognized variables can be ferreted out. Things will be learned about the operation that no one dreamed ever existed. When a time lag appears for mechanical reasons, there is a permanent performance record right at hand to indicate when and where repairs and replacements are needed.

After establishing the various studies required in the operation, the next step is to set up a system whereby all the data needed in plotting the charts are easily accessible to the plotter in a concise form. This system may vary with plants, depending on the supervisory organization. One thing which must be borne in mind, however, is that a complete story of the operation must be furnished the person who will analyze the charts and make suggested changes in the operation.

The plan used in the Hercules Mansfield time study was as follows.

Loose leaf log sheets were kept in duplicate for each batch processed. These loose leaf sheets were substituted for the log books previously used in the plant, thus making one copy available to the person doing the plotting and analyses. This person received all the data needed without interruption of the operation by removal of the log book from the operating area. Wherever possible, the operator doing the processing calculated his own time intervals and projected them on a plant control chart posted in the operating area. This method keeps the operator interested in his work and provides job satisfaction not otherwise possible. All log sheets were checked each morning by a foreman before

the duplicate copy was delivered to the office. Any errors found in the log sheet by the foreman were corrected, and information relative to the errors was passed along to the operator responsible for the errors.

In the office a complete up-to-date set of time cycle charts is carried on each product produced. These charts are regarded as performance or action charts rather than control charts. They are posted daily, using data available on the log sheet, and action can be taken immediately if corrections in the process are indicated. In these action charts, data on individual batches are plotted against control limits based on averages of subgroups of five. Although this is not in accordance with standard practice, the individual data are purposely plotted against control limits for averages to exaggerate the appearance of variation on the chart.

Such practice may be open to question, but this type of chart was selected because it was felt that this arrangement of the data would help to encourage the reduction of deviations in time from the average. If control limits for individual batches were used, the spread between the limits would be approximately 2.2 times as wide as when limits based on averages of five are used. There should then be roughly 99% of the points within these individual control limits, so that corrective action would seldom be called for. What was wanted was a chart that would show individual batch plottings and at the same time induce action to reduce deviations from the average time even though the deviations were within statistical limits.

Plotting individuals against control limits for averages, although not statistically correct, nevertheless has proved psychologically useful in establishing tighter control over variability in the process. As a further consideration, it may be emphasized that there are also a sufficient number of variables within each batch of product processed to make each point on the chart an individual study. It should not, however, be inferred from this discussion that the procedure used in keeping these action charts would be a generally useful substitute for standard control chart procedures; it is simply an adaptation that has proved useful in the circumstances with which this paper is concerned.

The control limits used were based on averages of data from the two kettles, and the individual batches were plotted on the plant chart in a color assigned to each kettle. Combining average data from the two kettles to establish the control limits was the extent to which combinations were made to reduce the number of charts required.

Before this study was instituted all operating personnel were briefed on the principles of quality control and were furnished with an elementary pamphlet on the subject showing how to make the necessary calculations for the various studies, and how to plot and use charts.

GENERAL IMPROVEMENT OBTAINED

The first positive results obtained from the use of these charts were realized through a study of the efficiency of the various operators. By initialing the runs made by the various operators it was easy to establish that some workers were more efficient than others, and to find at exactly what point in the operation the deviation existed. These points were reviewed with the operators and resulted in an immediate improvement, but this improvement was not permanent until action charts were set up in the operating area. The human factor was ever present throughout this investigation, but it was found that once action charts were introduced in the plant, time wasted by human cause was small as compared to mechanical failures.

An actual time study chart, Parts 1, 2, and 3, is shown. This chart is for one of the products and covers a period of 6 months. It is typical of similar charts for all products studied in this investigation. The chart shown is an actual duplicate of the action chart from the operation. Individual batch data for each kettle were plotted against control limits based on averages of subgroups of 5.

The January section of Part 1 shows data for operating performance before time study control was started. Immediately after the introduction of the time study at the beginning of February the chart shows a decided narrowing of the control limits in all respects. The improvement in the control limits of the two studies "Charging Time" and "Holding Time" can be attributed to the operating personnel. Since all mechanical devices used in charging the raw materials to the kettles functioned at a fixed rate, barring mechanical failures, efficiency depended upon the elimination of wasted time in making use of the equipment. Avoiding time lost in the holding time study also depended to a considerable extent on the human factor. The handling of control samples, the application of the various operating techniques, and the discharge of the product after the reaction was completed depended considerably on the dexterity of the operators.

The reason "Holding Time" did not show a marked decrease in time as did the other studies needs further explanation. In processing the particular product shown here graphically, there is a time-temperature relationship in the reaction rate which cannot be changed without changing the processing temperature. Holding time is a partial measure of the reaction rate for the process, though there are factors not related to the reaction which enter into this phase of the study.

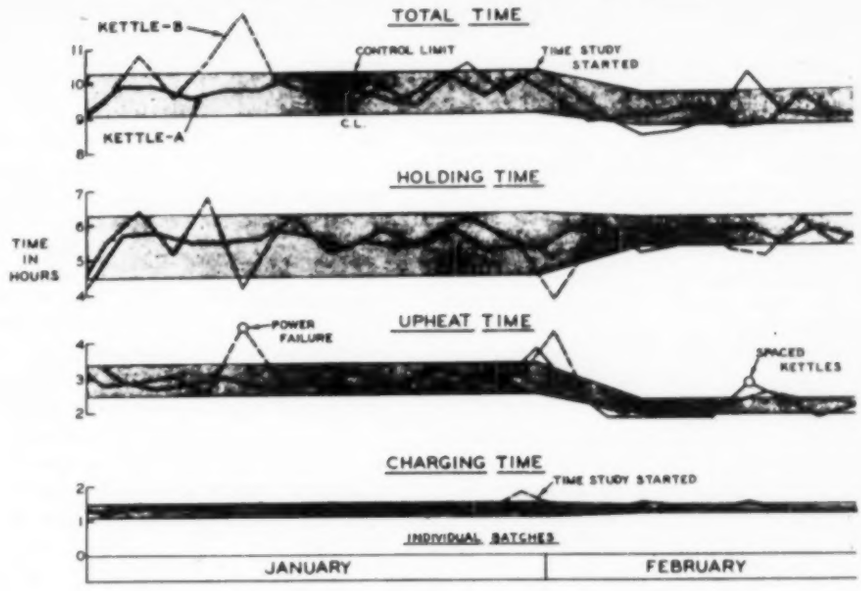
Actually, in a perfectly controlled process of this type, when "Upheat Time" decreases, not all, but a portion of the time saved will be sacrificed to a longer holding period. In this study it was coincidental that sufficient time was saved in the holding phase of the operation through control of factors not related to the reaction rate to compensate for a major portion of the time increase through the reduction in upheat time. The theoretical time balance for a given temperature which exists between upheat time and holding time has now been approached in this process. If the operation is controlled, this relationship should remain constant and should vary only when the top processing temperature changes as is shown in the April section of the next graph.

The remarkable improvement in "Upheat Time" was accomplished mainly by the careful distribution of the load on the boiler to obtain maximum heat when kettle demands were at their highest. This was merely a case of maintaining a uniform cycle so that one kettle could be on the upheat while the other was being held at top heat or was being finished off. Occasionally a kettle had to be held back or better spaced to accomplish this, but less time was wasted or lost in spacing than would have been lost had the kettles been operated at random as had been the previous custom.

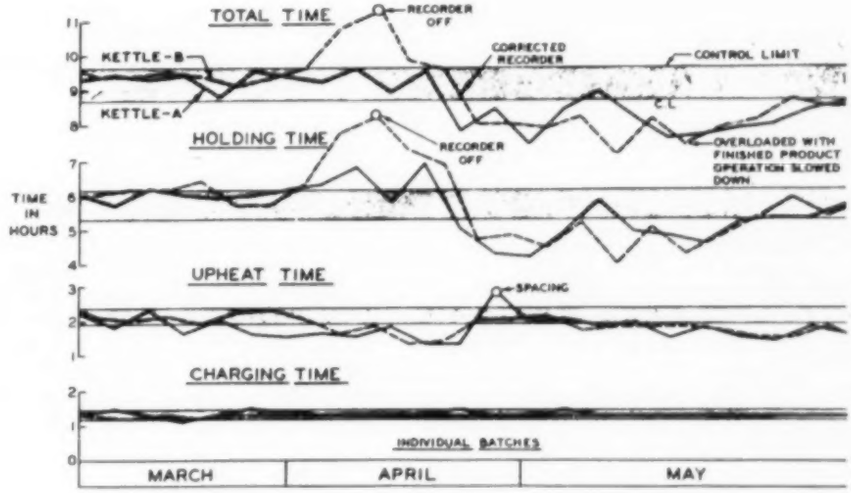
In Part 2 of the graph, it will be observed in the April section that the temperature recorder on Kettle B slipped, giving high readings. The resulting low kettle temperature slowed down the reaction, and this was reflected in a longer holding time. The consequences of this recorder failure indicated that slight temperature changes would not lower product quality. This lead was followed up and higher processing temperatures were introduced to shorten the cycle and increase production. This higher rate of productior was maintained through April and part of May, but the product was then coming off so fast that the finished product handling equipment proved inadequate to keep the material out of the way. Consequently, finished product load limits were established and kettle cycles were again lengthened, by lowering cooking temperature, to maintain uniform operation.

In Part 3 of the graph, deviations in the "Charging Time" illustrate how small variations in the time interval may be recognized and investigated. The charging phase of the operation gave little trouble until May when wet material and a power failure caused noticeable departure from the limits. During the June operation, the loading conveyor on Kettle A began to give trouble. Results for this kettle were out of control during the early part of the month, though the average time involved was very small. Elimination of this trouble amounted merely to a cleaning operation. The important factor is that such small time losses, involving only

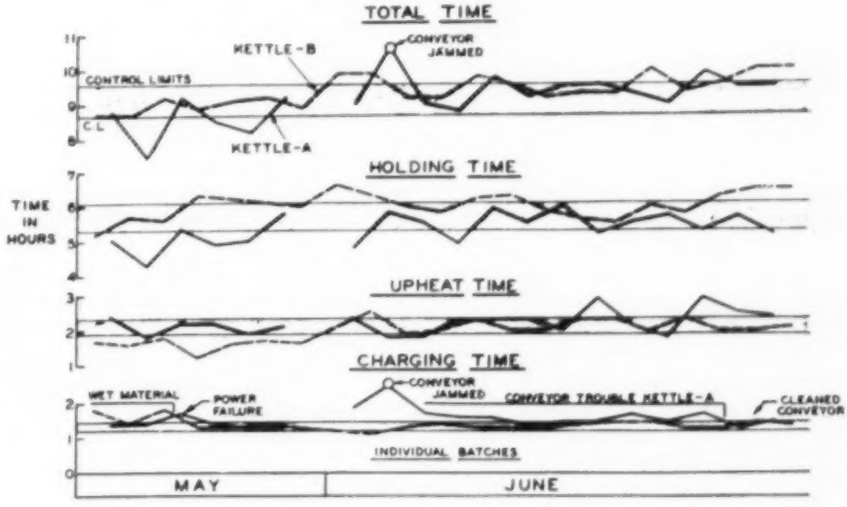
TYPICAL TIME STUDY OF BATCH PROCESSES



PART 1



PART 2



PART 3

10 to 15 minutes can be picked up from the control chart. It will be observed, also, that during May and June the holding time data indicated, by exceeding the upper control limit, that another processing temperature irregularity existed. This difficulty has been corrected since that time.

With sufficient patience and study, there should be found an explanation for every deviation in each batch. With proper equipment and proper control it should be possible to minimize the deviations so that the graphs tend to shrink down to a straight line drawn at the average time for each phase of the cycle.

Aside from the saving in operating time and the improvement in quality and uniformity of the finished product, through the use of this method of control, other advantages of no less importance may be obtained. Each day's use of appropriate charts for time study produces additional information to add to the experience in processing the product. The charts provide an accurate record of machine performance. Replacement of equipment and needed repair can be predicted. Inadequate and improperly designed equipment affecting production can be spotted. Additional advantages are:

(1) Provision of permanent records of operation in concise form.

(2) Graphic presentation of data which makes analysis easy.

(3) Provision of job satisfaction because workers can see and understand results.

(4) Provision of a medium for reporting data that is easily understood.

(5) Aids quick action in making changes in process.

Let's Try Analysis of Variance

JAMES A. FIZZELL
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When Shakespeare decided that Juliet should inquire, "What's in a name?", he also provided the answer that no significance need be attached to a mere name! Such an implication, however, does not take into account the psychological effect of a name, especially when that name is all that one knows about a subject. Take this subject analysis of variance for instance; it sounds rather formidable when you first encounter it. If, however, we call it just a systematic study of the variations in a process, you can immediately visualize some familiar machine or assembly or a complete manufacturing process or a whole departmental function, and you can then imagine variations occurring in its operation. Well, that is the kind of a picture that you really should have in order to start reading this article.

This statistical method may be thought of as a new tool which can be purchased for your use by the expenditure of a little effort and study. When a company buys a new and expensive machine, much study is given to the installation and operating instructions. The millwrights, electricians, and maintenance men have to learn how to install and to care for the machine. Then the operating personnel go through the process of learning to make the machine perform. This logical program is always taken for granted and industry accepts it. Now, if industrial men who are doing investigation and research work were to look upon analysis of variance with this same attitude, they would soon find themselves possessing a powerful tool that will really save time and money. The fear of this mysterious expression so glibly invoked by the experienced statistician must be dispelled so that industry can profit by the more widespread use of analysis of variance.

Two men who were deeply interested in making the subject of statistics so practical that it could depart from the school room and go into the shop or out on the farm were R. A. Fisher [1] in England and G. W. Snedecor [2] at Iowa State College of Agriculture. Both of these men have pioneered in the application of analysis of variance to biological experiments and to experiments in the testing of land, agricultural products, and soil treatments. Because of the fact that so many months are required to do experiments like these, it is necessary to get the maximum amount of information from each experiment. The system for analyzing variance accomplishes this for the experimental farmer, but it also works equally well for the physicist, the chemist, and the industrial investigator. It is by no means limited to agricultural and biological studies.

Since this scheme of taking and analyzing data is such a powerful one, you may naturally feel that one should be a trained statistician to understand completely the theoretical details behind the analysis of variance. With this feeling, we heartily agree, but we find that this requirement doesn't present quite as severe a limitation as you might fear. Just consider for a moment that there are hundreds of thousands of reasonably successful automobile drivers who can't explain the physics of a carburetor

EDITORIAL NOTE: Analysis of variance techniques have been used in several papers previously published in IQC. This paper opens the door to an expository treatment of this subject. Subsequent issues will contain a rather complete presentation of analysis of variance procedures under the joint authorship of staff members of the Ontario Research Foundation. Many of the questions and details of development intentionally left open in the present paper will be discussed in these forthcoming articles. M. E. W.

nor draw the diagram of the ignition system. Many of us who started using control charts of the $\bar{X}$ and R variety did so without a thorough knowledge of statistics, (what an understatement; we could hardly pronounce the word!) but we learned the mechanics of applying control charts and then picked up the theory later. If the routine is well planned, it is safe to do that. This introductory article is intended merely to attract attention, arouse interest, impart some knowledge, and invite further study of analysis of variance.

A PRACTICAL APPLICATION

Since nearly all companies have sales organizations or departments, a simple problem in the sales field should make an appropriate example. This problem is typical of some being solved, and it uses actual data. The sales department in this example decided that it wanted to study four sales territories in a certain section of the United States to see whether or not they had shown equal rates of growth in volume of 1947 sales over 1946 sales. As a general rule, the fluctuations from month to month and the variations in quarterly totals make it impossible to distinguish a significantly good or bad record unless it is extreme. This is a situation in which analysis of variance is commonly used.

The sales department submitted for this analysis a series of 48 figures representing the total volume of sales made by each of the four territories during each of the first six months of 1946 and each of the first six months of 1947. By taking a ratio of the January, 1947 sales to the January, 1946 sales for a given territory, one can obtain a figure which measures the increase in sales. There are 24 such ratios to be computed from the data, and these would be alike if all territories increased their sales volume in the same proportion. Naturally, you wouldn't expect to find the ratios identical, but you might discover that they are statistically alike.

The 24 ratios have been computed from the actual sales records for the months and years mentioned, and they are displayed in Table I. The average ratio is 1.616, which means that on the average, each territory yielded 61.6% more business in the first six months of 1947 than it did during the corresponding part of 1946. This figure is somewhat misleading, and it is not nearly as important as another but less obvious one. We need a figure to describe the variation which exists among the 24 ratios. The quantitative statistical measure of variation is called **variance** [3], and we must analyze this variance in order to find the answer to the question presented by the sales department.

TABLE I

Month	Territories			
	B	C	D	E
January	1.463	4.460	2.167	1.107
February	1.237	1.853	0.661	1.426
March	1.041	1.566	1.139	1.229
April	1.626	0.821	1.628	1.183
May	1.021	4.435	1.515	1.649
June	0.890	2.272	0.842	1.653

TABLE II

Month	Territories				Total for Row	Square of Total
	B	C	D	E		
January	—.537	2.460	.167	—.893	1.197	1.43281
February	—.763	—.147	—1.339	—.574	—2.823	7.96933
March	—.959	—.534	—.861	—.771	—3.125	9.76562
April	—.374	—1.179	—.372	—.817	—2.742	7.51856
May	—.979	2.435	—.485	—.351	0.620	0.38440
June	—1.110	0.272	—1.158	—.347	—2.343	5.48965
Total for Col.	—4.722	3.307	—4.048	—3.753	**—9.216**	**32.56037**
Square of Total	22.29728	10.93625	16.38630	14.08501	**63.70484**	**84.93465**

Sum of Squares of Row Totals	32.56037
Sum of Squares of Column Totals	63.70484
Square of Total of All Ratios	84.93465

SETTING UP THE PROBLEM

The plan for making this analysis is to go through a routine set of calculations and to gather the results of this arithmetic into a table which permits ready inspection and comparison of the figures. It is very important to keep the numbers small for ease in calculation, so all of the figures shown in Table I have had the digit 2 subtracted from them and have been copied into Table II. This yields some positive and some negative figures, but they are all fairly small. The totals for each row and each column have been recorded in Table II, and the square of each total has been selected from a handbook containing a table of squares.

On a separate sheet of paper (not shown here) the square of each of the 24 ratios was written down, and the sum of these squares was obtained. This sum is entered into the first space in Table III. Then the square of the sum of all 24 ratios has been selected from Table II and is divided by 24 to provide the second entry in Table III. The difference between these two entries is obtained and is extended to the right. All subsequent entries and subtractions in Table III are self-evident.

As a result of these operations, we obtain three important differences which we designate by the letters, T, M, and I. We use these differences to compute three estimates of variance based upon (1) the variation among totals of columns, (2) variation among totals of rows, and (3) interaction (a term we shall not try to explain) between rows and columns. The algebraic symbol for variance is sigma squared. The calculation and value of each of these three estimates of variance is shown in

Table IV. Note in particular the divisors $4-1=3$, $6-1=5$, and $(24-1)-(3+5)-(4-1)(6-1)=15$. Diminishing divisors in this way is always required in these calculations to yield what are called "unbiased" estimates of variance. The divisors 3, 5, and 15 are also called "degrees of freedom." It is not the purpose of this paper to elaborate on these terms.

The last variance is used as a basis for comparison with each one of the first two variances. The first variance, σ_T^2, is indicative of the variation in territorial sales growth rate, while the second variance is indicative of the monthly variation in sales growth rate. Thus, if σ_T^2 is significantly greater than σ_I^2, it strongly suggests abnormal differences between the performances of the four territories.[4]

Incidentally, since standard deviation is the square root of variance, we can digress for a moment to observe that the standard deviation among territories is $\sqrt{2.35951}=1.536$. This figure looks quite large when we recall that the average of all the ratios shown in Table I was 1.616.

TABLE III

Sum of squares of all ratios	25.89271	
Square of total of all ratios / 24	3.53894	
Difference		22.35377
Sum of squares of column totals / 6	10.61747	
Square of total of all ratios / 24	3.53894	
Diff. (T)		7.07853
Sum of square of row totals / 4	8.14009	Diff. 15.27524
Square of total of all ratios / 24	3.53894	
Diff. (M)		4.60115
	Diff. (I)	10.67409

TABLE IV

$$\sigma_T^2 = \frac{\text{Diff. (T)}}{\text{Territories}-1} = \frac{7.07853}{3} = 2.35951$$

$$\sigma_M^2 = \frac{\text{Diff. (M)}}{\text{Months}-1} = \frac{4.60115}{5} = 0.92023$$

$$\sigma_I^2 = \frac{\text{Diff. (I)}}{(\text{Ter.}-1)(\text{Mos.}-1)} = \frac{10.67409}{15} = 0.71160$$

TESTING THE RESULTS

The ratio of two variances is called "F". When the two variances are alike, F is unity. When the two variances are not alike, we must remember to place the larger one in the numerator of the ratio, so that F will always be greater than unity. The problem then becomes one of telling whether F is significantly greater than unity.[5]

In our quality control work with $\overline{X}$ charts, we were given a critical figure upon which to make a decision. When a plotted point was more than three sigma from the central line, it was considered beyond the limits of random deviations, and it was said to be a "significant" deviation. The exact numerical value of this 3σ limit was dependent upon several factors which involved the number of pieces in the sub-group. In our present test, we have a similar criterion which is dependent upon the number and arrangement of the rows and columns in Table II. This dependency is not a simple function, and consequently the critical figure is not computed for each test, but is selected from a table of critical F' figures.[6]

For the first comparison, let us set up the ratio

$$F=\sigma_M^2/\sigma_I^2=0.920/0.7116=1.293.$$

The critical figure for this comparison, found in G. W. Snedecor's table of F' values, is 2.90.* The interpretation is that in 5 cases out of 100 the F ratio may be expected to be equal to or greater than 2.90 purely as a result of random variations. It is clear in this case that the monthly variation is not significant, since F is smaller than F'.

For the second camparison, let us set up the ratio

$F-\sigma_T^2/\sigma_I^2=2.359/0.7116=3.31$. The critical F' figure for this comparison is 3.29. Since F is larger than F' in this case, there is evidence of significant variation among the totals for the territories. Their records should be studied to see whether there is some assignable cause for this variation. This is the recommendation that was made to the sales department which had submitted the original problem.

Further investigation showed that territory C had done a noteworthy job in 1947, and that its methods should be studied in planning the 1948 sales program. It should be noted that this analysis of variance disclosed the existence of a significant variation among territories and focused attention upon one territory, suggesting a more searching study for valuable information.

There are numerous assumptions and restrictions which must be observed in designing or setting up a new analysis of variance scheme; knowledge and experience are required to obtain maximum benefits. If, however, prepared tabular forms, such as II, III, and IV, can be filled from observed data, one may make a useful start with this technique and proceed to test the calculated F ratios against the critical F' values in Snedecor's F table. The numerous textbooks touching upon various phases of this subject list analysis of variance schemes with different degrees of

*Directions for entering and using this table are given in the table itself. See reference 2 and 6.

complexity, and they explain the reasoning back of each scheme. The beginner should start with a prepared table to avoid most uncertainties. It can be stated with assurance that time spent in studying this fascinating subject will be a profitable investment.

REFERENCES

1. R. A. Fisher, "Statistical Methods for Research Workers," (revised edition); Oliver and Boyd, Ltd., Edinburgh, 1941.
2. G. W. Snedecor, "Statistical Methods;" Collegiate Press, Inc., Ames, Iowa.
3. Paul R. Rider, "An Introduction to Modern Statistical Methods;" John Wiley & Sons, Inc., New York, 1939.
4. R. A. Fisher, "Design of Experiments;" Oliver and Boyd, Ltd., Edinburgh, 1942.
5. John H. Smith, "Tests of Significance; What They Mean and How to Use Them;" The University of Chicago Press, Chicago, Illinois, 1942.
6. For table, see (2) above or see Freeman's "Industrial Statistics" or Kenney's "Mathematics of Statistics" (part two).

A Training Program Becomes A "Clinic"

GEORGE A. HUNT

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A series of "What's Your Problem" meetings of the Syracuse Section constituted a training program where problems of individual members were described and discussed in a Mark Hopkins sort of way, with the chairman on one end of a log and the members of the local group wedged on the other end. Any member would start off by asking, "How would you . . . ?" Other members, or the chairman, after many questions to define the problem clearly, would describe how they would tackle the difficulty. These meetings were popular. Even at other meetings, after listening politely to a visitor for 45 minutes, members not infrequently started a "What's Your Problem" session spontaneously. The ability of the society to survive in the first year of its organization was due to this type of meeting*.

Such programs were interesting, but as the local quality control group became larger, it grew more and more difficult to persuade new members to present their problems. The "What's Your Problem" meeting then developed into a more elaborate program, whereby the problem was presented by several individuals who developed specific phases or answered questions concerning that phase. After discussion, solutions were suggested by the members. If the problem had been solved by the group presenting it, this solution was given and compared with the solutions offered by the members.

Although the program committee of the Section planned further meetings along these lines for the current year's meetings, and began to scout for problems encountered by local members, it became evident that there was a much better source of material. Members interviewed and asked if they could furnish data or material for presentation of a problem were likely to reply, "You say that you want a problem? Well, Joe has a problem that is a problem. He's in real trouble." Neither Joe nor anyone in Joe's company were members of ASQC, or perhaps Joe had joined very recently, was unfamiliar with quality control, or didn't know how to apply it in his work.

The answer was obvious. A committee contacted members of Joe's company, talked over his troubles, and asked for permission to present his problem at a meeting of the local section of ASQC. A problem was defined, data collected, and technical terms defined so that those unfamiliar with the language of the industry could grasp the discussion. At the same time it was arranged to have representatives of the Control Department and the Laboratory attend the meeting to answer questions and to participate in the discussion.

A mimeographed letter was sent to members of the local section ten days prior to the meeting and is shown below.

WHAT'S YOUR PROBLEM?
Syracuse Section, ASQC

Problem: How may principles of Quality Control be applied to foundry problems? Specifically, how may the number of rejected castings be reduced in this foundry?

Job Description:
Castings: Aluminum
Weight: Ten pounds
Equipment: Cope and Drag, Overhead Sand, Jolt Squeeze Machine.
Core: Green Sand (unbaked)
Pins: Four baked (dry sand) pins
Output: Five hundred castings per day with eight men.

A **Breakdown Sheet** indicating major causes of rejections is enclosed and shows:

Number of rejects per cause per day.

Weekly total of rejects per cause.

Weekly total of rejects for all causes.

Three-week total of rejects per cause.

*As early as the Spring of 1944, members of the Syracuse Society brought problems to the follow-up meetings after the original "8-day course". The "What's Your Problem" type of meeting was developed by Mr. Richard Coolbaugh, Easy Washing Machine Corporation (President of the local Society at that time) from this initial experience.

BREAKDOWN SHEET

Cause of Rejection:	DAY OF MONTH																		
	6	7	8	9	10	Wkly. Total	13	14	15	16	17	Wkly. Total	20	21	22	23	24	Wkly. Total	3-Wk. Total
Sand	23	11	22	24	17	97	29	28	18	12	33	120	22	13	16	15	16	82	299
Mis-run	2		2	1	3	8	4		6	4	1	15	1		1	1	1	4	27
Blow																	1	1	1
Shift		15			3	18	1	1		3	7	12						0	30
Cut															1			1	1
Broken	11	2	3	1	4	21	3	3	4	4	3	17	7	4	3	7	4	25	63
Drop	1	1	2	3	1	8	4	3	3	2	1	13	3	4	2	1	2	12	33
Corebreak	1		15	5	2	23	4	5	1	8	3	21	8	1	4	13	12	38	82
Run out	2			1	1	4	1	2	2	1		6	1			1	3	5	15
Core missing					1	1	1		1		1	3			1	1	1	3	7
Crush											6	6	4	2	3			9	15
Daily Total (Scrap)	40	29	44	35	32	180	47	42	35	34	55	213	46	24	31	39	40	180	573
Production	478	514	500	470	530	2492	430	494	500	505	465	2394	464	500	473	518	570	2525	7411

Daily and weekly production.

A beginner's glossary of foundry terms (written by a beginner) may be helpful:

Sand: Sand forms the mold. Such properties as moisture content and the clay coating on the granules, are important and are controlled by frequent laboratory analysis. The cause of rejection labeled "sand" is due to the sand washing into the metal, the metal and sand mix, the sand later falls out giving the casting poor appearance or weakens the structure of the casting.

Mis-run: Metal fails to run in the mold.

Shift: Mold shifts. Top and bottom (Cope and Drag) mismatched.

Cut: Mechanical error of "saw man". Saw cuts metal. Carelessness.

Broken: Self explanatory. Rough handling of casting. Carelessness.

Drop: Part of the mold drops and prevents flow of metal.

Core break: Core breaks, drops into mold, and prevents flow of metal.

Run-out: Metal runs out from poor fitting joints of mold or through failure of the wall of the mold.

Core missing: Self explanatory. Carelessness.

Crush: Ill fitting core or mold (oversize or out of place) presses into mold cavity and deforms sand—"causes a crush".

Reports of laboratory analyses are sent to a representative of management, to the Control Department, and to the Foundry Foreman. It is possible to take action promptly whether trouble is discovered by the foundry or anticipated by the laboratory, because of direct contact between the foundry foreman and the laboratory.

The problem exists in a local foundry. Members of the foundry's staff will be present at our meeting to answer your questions. They in turn are presenting this problem to you. Can you apply the principles of statistical quality control? What would you do if you were employed by a foundry?

With the above letter at hand, the meeting was held in a class room with ample blackboard space. The discussion was lively, and member interest was keen. After two hours, the janitor finally gave up and handed the chairman a note asking him to turn out the light — that he was going home!

Many members subjected the breakdown sheet (causes of scrap) to statistical analyses. Some members looked for correlations of causes of rejections, several set up control charts and applied significance tests to the variability in manufacture.

The discussion brought out several points of interest and enabled the members to make several recommendations:*

1) Records were not adequate. Although the breakdown sheet indicated causes of rejection, the data given showed castings inspected on that day, rather than the castings poured. From the present records there was no way to trace a rejected casting to a given melt or to a given day of pour. There should be adequate records and someone to keep and interpret them.

2) Sample castings of this job are shipped daily to the customer for machining, but samples are taken from the first two of about eleven melts per day. More reliable information could be expected from a more representative sample.

3) Delayed inspection is unsatisfactory here. "On-the-spot" inspection together with segregation of castings of each melt until completion of inspection is essential for data suitable for control of the process. For example, the natural subgroup of castings is a melt, or approximately 40 castings. The rejected castings of the melt should be classified as belonging to the first ten, second ten, third ten, or fourth ten poured. If any trend in the process was observed, cost accountants should determine the economic size of the melt to minimize cost of the scrap due to changes in conditions during pouring.

4) Handling of sand is inadequate. It is impossible with present equipment to prevent stratification of the sand without a mixer or blender. Samples of sand taken at hourly intervals are not representative without such blending. Control charts at this stage of the process would give little essential information under present conditions.

* These are conclusions and recommendations of the members of the local section. Members of the staff of the foundry do not necessarily concur with them.

5) High rejection rates caused by sand are due to faults of equipment as well as to the physical condition of the sand. Crumbling during assembly of the mold or transport of the mold along the line, point to the need of more careful handling or improved equipment for assembly of the mold and of conveyors in the production line.

6) Scrap produced for reasons of carelessness should decrease through instruction and maintenance of control charts on individual performance.

It is evident that the Syracuse Section will have more meetings of this type. The presentation of a problem and subsequent discussion serves as a member training program, especially when many members participate. Members must review the principles of quality control and apply basic control methods to a problem, frequently in a field outside their own. Essentially, each member must ask himself, "What would I do if I were employed by this industry?"

Meetings such as this are more than member training programs. Such meetings become "clinics". The word, clinic, (derived from the Greek, **klinikos**) pertains to the bed, and usage associates the word with the sick bed — not a show, a demonstration, or a convention as frequently used by quality control groups. The Syracuse Section thus combined its "What's Your Problem" member training program with a "clinic" in the same sense that a treatment is administered to an ailing or deficient industrial organization or a department of an otherwise healthy organization.

Most industries would resent the inference that they were sick, but in the eyes of a Quality Control Engineer, and in the face of present day competition, any industry countenancing waste or preventable scrap is ailing or deficient and can use properly administered statistical quality control.

FIRST ANNUAL CLINIC AND GAGE EXHIBIT OF THE ST. LOUIS SECTION, ASQC

On November 21, the St. Louis Section held its First Annual Clinic and Gage Exhibit. The object of this clinic was primarily to present to local industry a brief introduction to statistical quality control. In this endeavor, the speakers proved to be particularly successful.

The clinic consisted of three technical sessions: "Control Charts for Measurements," by Irving W. Burr, Associate Professor of Mathematics, Purdue University; "Control Charts for Attributes," by J. H. Batchelor, Industrial Engineer, Washington University; and "A Study of Sampling," by B. H. Nissen, Director of Brewery Division Laboratories, Anheuser-Busch Incorporated.

The luncheon featured the sound film in color, "Modern Quality Control," with introductory remarks by Mr. S. Collier, Director of Quality Control, Johns-Manville Corporation, which made the film. This excellent film was well received, and proved to be most stimulating and informative to all.

The day's activities concluded with a banquet during which the history of the St. Louis Society for Quality Control was briefly reviewed by this Section's President, Kort K. Pfabe of the Carter Carburetor Corporation. The principal speaker of the evening, Mr. George D. Edwards, President of the American Society for Quality Control, then presented a short history of the science of statistical quality control, and of the development of the American Society. Mr. Edwards closed with a few words on the present activities and plans of the American Society, and its promise for future development.

The success of this event, with a total of over seven hundred persons attending the five meetings, has amply rewarded the members of the St. Louis Section for their efforts in making this clinic possible.

IMPORTANT NOTICE

TO 1946-1947 MEMBERS WHO HAVE NOT RENEWED THEIR MEMBERSHIP FOR 1947-1948

Under the Constitution of the American Society, all 1946-47 members who had not renewed their membership for 1947-48 by remitting dues for the new year before 1 January, 1948, are required to be placed on the Suspended List and to receive no further issues of Industrial Quality Control or other Society Publications.

Since this is the first year in which the above rule has been in effect, the Society has waived it to the extent of mailing this issue of the magazine to all members who have not yet renewed. No further waiver of the rule will be made, however, and the names of those who do not renew their memberships by 15 February will be removed from the mailing list for the March and subsequent issues.

All memberships renewed before 15 February will appear in the 1947-48 Year-Book of the Society. All members contemplating transfer to a higher grade are also urged to file their applications at the earliest possible moment, so that ample time will be available for processing the applications and securing proper Year-Book entries before the date noted.

CONFERENCE PAPERS

Second Annual Midwest Quality Control Conference

$3.50 Postpaid

Order from: Alfred L. Davis, Treasurer, ASQC
Rochester Institute of Technology, Rochester 8, N. Y.

AMERICAN SOCIETY NEWS

BOARD AND COMMITTEE MEETINGS DURING ROCHESTER CONVENTION

Many Board and Committee members will be present for the Convention in Rochester, who would not ordinarily find it possible to undertake travel for the sole purpose of attending Board or Committee meetings. It will therefore be highly desirable for Board and Committee Chairmen to take every possible advantage of this circumstance, and to plan such meetings in Rochester at that time.

In addition, the President and Vice-President of the Society plan to meet during the Convention with all Section Chairmen or Presidents and all Section Vice-Chairmen or Vice-Presidents. The Executive Secretary and the Treasurer of the Society are planning a similar meeting during the Convention with all Section Secretaries and Section Treasurers.

If all Boards and Committees hold meetings during the Convention, seventeen such sessions will be involved. The amount of "open" time during the Convention is limited, so that a number of meetings will thus have to be scheduled simultaneously. A schedule has been worked out on this basis, arranged to avoid conflicts so far as possible, and is set forth below.

Monday, 16 February

10:30 A.M.-12:00 Noon
- Committee on Programs and Speakers
- Nominating Committee

4:00 P.M.-6:00 P.M.
- Board of Directors

Tuesday, 17 February

10:30 A.M.-12:00 Noon
- Section Chairmen or Presidents and Section Vice-Chairmen or Vice-Presidents
- Section Secretaries and Section Treasurers
- Editorial Board
- Committee on Membership
- Shewhart Medal Committee
- Committee on Relations with Educational Institutions
- Committee on Constitution and By-Laws

2:30 P.M.-4:00 P.M.
- Advertising Committee

4:00 P.M.-6:00 P.M.
- Committee on Relations with Other Technical Societies
- Committee on Publicity and Public Relations
- Committee on Professional Ethics and Qualifications
- Examining Committee
- Committee on Standards
- Auditing Committee

So far as possible, the above meetings will be held in the small Committee Rooms at the Rochester Chamber of Commerce, though it may be necessary to hold some of them in nearby hotels. The location of each Board or Committee meeting will be given in the Convention Program, and will be posted at Convention headquarters in the Chamber of Commerce.

Board and Committee Chairmen will provide the members of their several groups with further information as it becomes available regarding the meetings scheduled above. In the meantime, Board and Committee members are urged to arrange their schedules so that they can be present at the times indicated.

EXECUTIVE COMMITTEE MEETS

The Executive Committee held a two-day meeting at the Rochester Hotel in Rochester, New York, on 6-7 December. All but two of the eleven members of the Committee were present.

The Executive Secretary reported a highly unsatisfactory proportion of membership renewals, and an equally highly satisfactory showing in new memberships and in transfers to the Senior Member grade. Reports from the Regional Directors present indicated quite a number of additional renewals in process between Section secretaries and the Executive Secretary's office, but even with these included, the Executive Committee felt that prompt and affirmative action is necessary to correct the situation.

Regional Directors undertook to secure monthly reports on renewals from each Director in their several Regions, and to transmit these promptly to the Executive Secretary. The Executive Secretary will combine and duplicate these reports in a single tabulation each month, and will transmit this tabulation to all American Society officers and Directors, to the Executive Chairman of the Membership Committee for distribution to all members of his Committee, and to all Section Chairmen and Secretaries.

Each Regional Director also undertook to spur the drive for membership renewals in each Section in his Region.

The Treasurer presented a report showing a balance of $4,957.76 on hand as of 3 December, 1947. Minor modifications in the tentative budget for 1947-48 were approved. It was reported that one or two Sections still have to adjust their fiscal years to terminate at 30 June as required by the Constitution. The Regional Directors concerned agreed to follow these Sections and to urge that they take the necessary action so as to avoid the billing difficulties experienced this year.

The Executive Secretary reported a fair return of the post-card questionnaires sent to all members for information required in connection with the next Year-Book. A considerable number of cards still remain to be returned, however, and Regional Directors undertook to follow up this matter with the Sections in their several Regions.

The President reported that in accordance with the authorization given him at the previous meeting of the Executive Committee, he had accepted the invitation of the Rochester Section to hold the Second Convention of the American Society in Rochester in conjunction with the Fourth Annual Quality Control Clinic of the Rochester Section. He also reported that he had invited the members of the Planning Committee of the Rochester Section to meet with the Executive Committee for the purpose of working out further plans and details in connection with the Convention and Clinic.

The joint meeting of the Executive Committee and the Planning

Committee of the Rochester Section was held on the afternoon of 6 December. During the two hour session which ensued, agreements and decisions were reached with respect to all matters which were susceptible of conclusion at that time. The decisions with respect to the program and other arrangements, provisions for reservations both for the sessions and for hotel accommodations, etc., are set forth in detail elsewhere in this issue of the magazine.

Following conclusion of the joint meeting with the Rochester Planning Committee, the Executive Committee devoted substantial discussion to plans and preparations for the 1947-48 Year-Book of the American Society. Final decision as to publication date and other arrangements in connection with the Year-Book was delegated to the President and the Executive Secretary, but the Regional Directors undertook to urge their several Sections to press for membership renewals and for the enrollment of new members as rapidly as possible so that a minimum number of renewals and new members would fail of inclusion in the Year-Book. Regional Directors also undertook to follow their several Sections and to urge them to make sure, so far as possible, that all of their National Committee nominees and all of their local Section officers are members of the American Society as well as of their local Sections. Only American Society members can be listed in any capacity in the Year-Book, and all non-American-Society members will hence have to be omitted.

Numerous other matters were given detailed consideration during the two-day meeting of the Executive Committee, and action taken in connection with a number of them is recorded elsewhere in this issue of the magazine.

PROFESSIONAL CONSULTANT ADVERTISING

The Committee on Professional Ethics and Qualifications has had under consideration for some little time the matter of professional consultant advertising in the magazine. It has now recommended to the Executive Committee that, as a service to members, such advertising in the form of "business cards" be accepted from corporate members of the Society only, under certain conditions.

This recommendation was carefully considered by the Executive Committee at its meeting in December, and was approved.

Professional Consultant Advertising will hence be accepted hereafter by the Society for publication in Industrial Quality Control under the following conditions:

1. The advertisement must be inserted by a corporate member of the American Society, by a partnership of which the American Society corporate member is a partner, or by a corporation of which the American Society corporate member is an officer or director. The name of the American Society corporate member, and his grade of membership in the Society, must appear in the advertisement.
2. The advertisement must be in the form of a "business card" adapted to occupy a space one inch by two inches in size in the magazine. The text matter shall be limited to the name, address, telephone number, etc., of the consultant, his grade of membership in ASQC, and a short conservative statement of the character of services offered. The name of the partnership or corporation with which the ASQC member is connected, may be mentioned in addition to his own, if desired.
3. Such advertisements will appear under a column headed "CONSULTING SERVICES." The following statement will appear immediately under this heading and above the advertisements: "Responsibility of the American Society for Quality Control, Inc., for Consulting Services advertising is limited to certification that advertisers hold the grade of membership in the Society stated in their advertisements. Qualification requirements for the several grades of membership are set forth in the Constitution of the Society."
4. Consulting Services advertising will be accepted for insertion in the March, 1948 issue of Industrial Quality Control, and for subsequent issues appearing bi-monthly thereafter.
5. Copy for Consulting Service advertisements should be sent to

   Mason E. Wescott
   Chairman, Editorial Board
   Lunt Hall,
   Northwestern University
   Evanston, Illinois,

   and must be in his hands by the 10th of the month preceding the month of issue.
6. Rates for Consulting Service business cards (1" x 2") are as follows:

   For one insertion ....$ 7.00
   For three insertions .. 18.00
   For six insertions 30.00

   Bills for such advertising will be rendered by the Treasurer immediately following the first insertion.

EMPLOYMENT ADVERTISING

At its meeting in December, the Executive Committee discussed at some length the desirability of employment advertising in Industrial Quality Control, and concluded that this should be undertaken as a service to those members of the Society who may be looking for positions.

"Positions Available" advertising will hence be accepted for insertion in the March, 1948 issue of the magazine, and for subsequent issues appearing bi-monthly thereafter.

"Positions Wanted" advertising will be accepted on a similar basis from corporate members of the Society only.

Rates for both types of employment advertising will be 50 cents per column-line per insertion, with a minimum charge per insertion based on five lines and a maximum space not to exceed 20 lines per insertion.

Employment advertisers may direct in their copy, if they desire, that replies be sent to the office of the Society at 305 East 43rd Street, New York 17, N. Y. In this event, however, identification codes should be registered with the Executive Secretary in advance, or should be secured from him. The identification should then be included in the copy.

Copy for Employment Advertising should be sent to

Mason E. Wescott
Chairman, Editorial Board
Lunt Hall,
Northwestern University
Evanston, Illinois,

and must be in his hands by the 10th of the month preceding the month of issue. Bills will be ren-

dered to advertisers by the Treasurer immediately following publication.

CODE OF ETHICS

Ever since its appointment something over a year ago, the Committee on Professional Ethics and Qualifications has had before it the problem of drafting and recommending a Code of Ethics for adoption by the Society. During this intervening period, the Committee has devoted much time, study, and thought to the problem. It has examined and compared the codes already adopted by other societies, and it has discussed the desirable provisions in such a code with many members of this and other societies.

On 17 October, the Committee forwarded to the President, for submission to the Executive Committee, a draft Code of Ethics which it recommended for adoption by the Society. In the main this draft code is an abridgment of a considerably longer and more detailed one already adopted by several societies and now recommended for adoption by engineering societies in general. Because of its length, there has been some reluctance on the part of some societies to adopt this longer code, and a number of them have adopted abridgments quite similar in form and content to that now recommended by the Committee on Professional Ethics and Qualifications.

The President submitted the Committee's recommended draft, with his endorsement, to the Executive Committee at its meeting in December. After careful consideration, the Executive Committee voted unanimously to submit the recommended draft to the Board of Directors with the endorsement and recommendation of the Executive Committee that the Board adopt it formally as the Code of Ethics of the Society in accordance with Sections **33. b.** (7) and **52. b.** of the Constitution.

Copies of the draft have accordingly been forwarded by the President to each member of the Board of Directors for his consideration and for subsequent expressions of his opinion favoring or opposing its adoption as the Code of Ethics of the Society.

The draft Code of Ethics, as submitted to the Board of Directors, is printed in full in this issue of the magazine.

DRAFT

CODE OF ETHICS

AS SUBMITTED AND RECOMMENDED BY THE
COMMITTEE ON PROFESSIONAL ETHICS AND QUALIFICATIONS
AND AS ENDORSED AND RECOMMENDED BY THE
EXECUTIVE COMMITTEE
FOR ADOPTION BY THE
BOARD OF DIRECTORS
ON BEHALF OF THE
AMERICAN SOCIETY FOR QUALITY CONTROL

In order to maintain the dignity of his chosen profession and to render proper service to individuals and the public, it is the duty of each corporate member of the Society:

1. To carry on his professional work, with fairness to all concerned, fidelity to clients and employers, and devotion to high ideals of personal honor;
2. To treat as confidential his knowledge of the business affairs or technical processes of clients or employers;
3. To inform a client or employer of any business connections, interests, or affiliations which might influence his judgment or impair the equitable quality of his services;
4. To accept compensation for a particular service from one source only, except with the full knowledge and consent of all interested persons;
5. To advertise only in a modest manner and with due regard to the dignity of the profession;
6. To refrain from using improper or questionable methods of soliciting professional work;
7. To avoid using unfair means to win professional advancement;
8. To refrain from associating himself with, or allowing the use of his name by, any enterprise of questionable character;
9. To co-operate in building up the engineering profession by interchanging information and experience with other engineers and students, and by contributing to the work of engineering societies, schools, and the scientific and engineering press, without disclosing confidential matter;
10. To refrain from using the advantages of a salaried position to compete unfairly with others;
11. To give due credit to the work of others when using all or part of their material;
12. To consider his membership in this Society as affording him distinct opportunity to apply his special talents for the service of mankind.

YEAR-BOOK 1947-1948

Because of the excessive load of Society work on the Executive Secretary and on others involved in its preparation, work on the Year-Book for 1947-48 is not as far along at this time as had been anticipated. The closing date for the Year-Book has hence not yet been set, though it probably will be in the near future.

All renewals, new memberships, and transfers to higher grades of membership effected prior to 15 February, 1948, will definitely be included in the Year-Book, however, and members or prospective members are urged to get their renewals and transfer or membership applications into the hands of the Executive Secretary by that date in order to insure their inclusion in correct form. Corporate members who have not renewed their membership for 1947-48, are reminded that this is the last issue of the magazine which they will receive until their renewal has been effected.

When you specify test loads do you . . . hope for them? . . . grope for them? . . . or make sure of them THIS WAY?

EACH LOT OF EVERY ITEM AS IT CLEARS HUNTER FINAL INSPECTION

is

RANDOM SAMPLED

for

SPECIFIED LOAD TEST

with

RESULTS RECORDED IN THE FORM OF A FREQUENCY DISTRIBUTION

on

A QUALITY REPORT (QR)

which

BELIEVE IT OR NOT

HUNTER PRESSED STEEL COMPANY

HUNTER
Science in Springs

SPRINGS, METAL STAMPINGS, WIRE FORMS,
MECHANICAL & ELECTRICAL ASSEMBLIES

IS MAILED

TO CUSTOMER

PRIVATE CORNER
for
INSPECTORS
QUALITY BUGS
SPRING USERS
NON-SPRING USERS
ANYONE ELSE

HUNTER PRESSED STEEL COMPANY
LANSDALE, PENNSYLVANIA

Gentlemen: I'm interested. Please send me without obligation____ copies of "The Statistical Method for Control of Quality", including an explanation of the Hunter Quality Report Service.

Name_____

Title_____

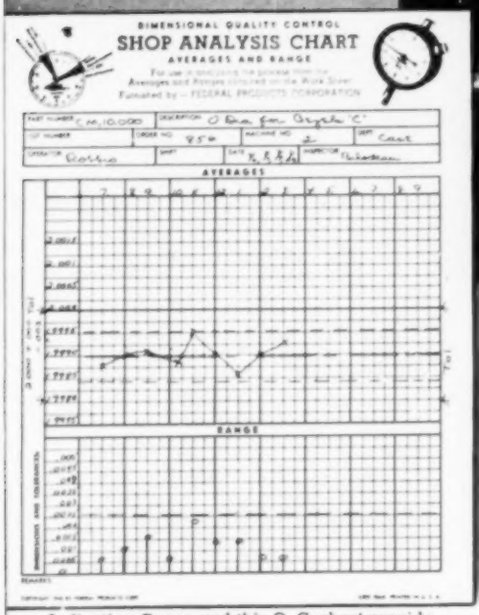
Company Name_____

Street Address_____

City_____ Zone____ State_____

DIMENSIONAL QUALITY CONTROL

Dimensional quality is controlled directly at the machine.



Indicating Gages and this Q. C. chart provide the data and means to keep dimensions under control.

3 GAGING SYSTEMS

MECHANICAL

Adaptable and economical Dial Indicating Gages for the usual control requirements.

AIR

A new air System for extremely fine finishes and measurements. Many new exclusive features.

ELECTRONIC

An extremely fast, sensitive instrument with a multitude of possibilities.

Economical Control at Production — a Management Tool

Federal Indicating Gages plus Quality Control Charts Make Graphic what is happening at the Machine

The case history of the application illustrated above of Quality Control by statistical methods, based on the accurate readings of the Federal Indicating Gage, shows the practical result of controlling a critical dimension of our own product.

A piece intrinsically difficult to turn, a dimension hard to maintain, and an out-of-round condition prohibited by assembly conditions. Rejects, rework and scrap ran high, unit hours low. Imperfections at this operation directly fostered inaccurate performance of the finished instrument.

After the introduction of Quality Control scrap figures dwindled by 75%. Even greater satisfaction was gained from the even flow of homogeneously dimensioned pieces coming from this operation.

With Quality Control and Federal Indicating Gages inaccuracies are discovered *before* they develop, operator interest increases, wasted time and material disappear and a product is made that renders better service to the ultimate user.

Write for the Federal Quality Control Primer, a simplified, practical way to apply Quality Control.

FEDERAL PRODUCTS CORPORATION

1144 EDDY STREET PROVIDENCE 1, R. I.

The Federal Quality Control Primer will be mailed to anyone interested in this new management tool.

**Quality Control by Statistical Methods.*

BRANCH OFFICES

Atlanta • Avondale, Ariz. • Chicago
Cleveland • Dallas • Detroit • Greensboro, N. C. • Hartford • Houston
Indianapolis • Los Angeles • Memphis
Milwaukee • Minneapolis • Montreal
New York • Philadelphia • Pittsburgh
Portland, O. • Rochester • San Francisco
Seattle • St. Louis • Toronto
Tulsa • Windsor

★ ★ ★ ★ ★ **FEDERAL** ★

PRECISION MEASURING INSTRUMENTS